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A Multi-Agent System for Facility Location Problems

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Content

- Research Plan
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- Binary vs Proportional Models
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Research Plan

	Publication's title	Fulfilment period		Notes
		From	To	
1.	**Review and analysis of scientific research related with the theme of doctoral thesis (in Lithuania and abroad):**			
1.1.	Identifying the project specification and object of the dissertation research.	2023 y. IV quarter	2024 y. I quarter	
1.2.	Analysis of competitive facility location problems and their solution methods.	2023 y. IV quarter	2024 y. III quarter	
1.3.	Analysis of multi-agent systems and their application to facility location	2023 y. IV quarter	2024 y. II quarter	
2.	**Prosecution of scientific research:**			
2.1.	**Formation of study methodology:**			
2.1.1.	Formulation of the aim and objectives of the dissertation to identify quantitative and qualitative research methodologies of the problem	2024 y. IV quarter	2025 y. I quarter	
2.1.2.	Selection and description of methodologies	2024 y. IV quarter	2025 y. I quarter	Below are the intially identified research methods for this study. further need to investigatesuitable methods. 1. Literature Review: 2. Conceptual Framework: 3. Research Design: 4. Data Collection: 5. Agent-Based Modeling: 6. Data Analysis Techniques: 7. Validation and Verification: 8. Ethical Considerations:

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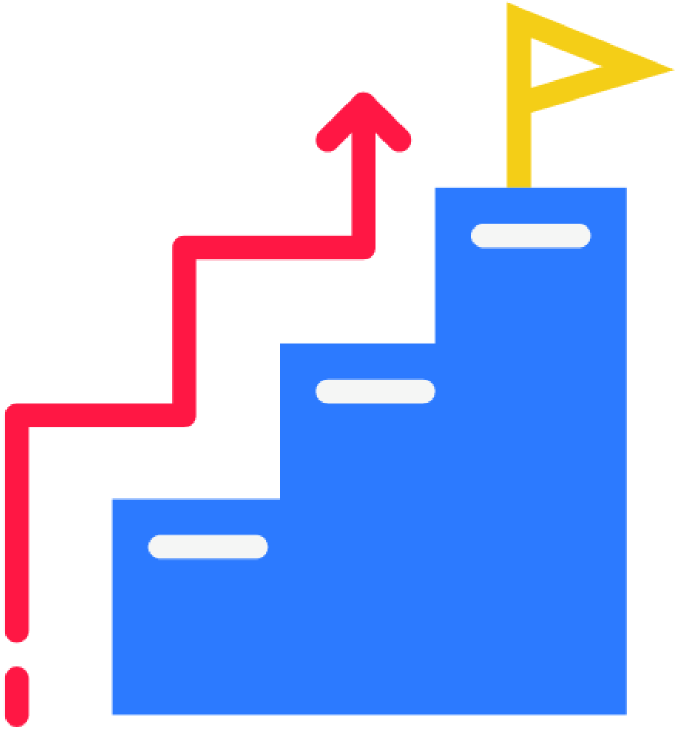
Goal

- The research studies supreme goal to create a robust Multi-Agent System (MAS) platform for dynamic facility location optimization, overcoming limitations of traditional techniques like static nature and inability to adapt to market changes.



Research Objective

- **Enhance** Facility Location Decision-Making **Efficiency** through a Multi-Agent System
- Develop Appropriate **Agent Architectures** and Communication Protocols to **Solve FLP** Issues
- **Integrate** all important **stakeholders** of FLP into the MAS application to get mutual benefits
- **Evaluate performances** of the MAS application Addressing Facility Location Challenges

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Research Problem

1. How can **real-time** data and **dynamic variables** be effectively **integrated** into facility location decisions in dynamic and uncertain environments by a Multi-Agent System (MAS)?
2. How can facility location problems be addressed by practical solutions that **integrate stakeholders**' needs and enable adaptive decision-making processes provided by a MAS application?
3. How can **innovative** MAS approaches address the lack of effective solution methods for **dynamic facility location problems**, where demand points or facilities undergo changes over time?

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Introduction - FLP

- Facility Location Problem is a critical aspect of operational management.
- It involves minimizing costs, improving customer satisfaction, and increasing profitability.
- Inefficient facility locations can result in excess costs throughout the facility's lifetime.
- Facility location significantly impacts revenue, costs, and customer service.
- Optimal facility location decisions are crucial for expanding market share and minimizing cost factor.

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Classification of FLP

- **Number of Facilities** – Single/Multi
- **Demand Points** – Continuous/Discrete
- **Capacity** – Capacitated/Un-capacitated
- **Time Dynamics** – Static/Dynamic
- **Competition** - Competitive/Non-competitive FLP
- **Number of Objectives** - Single/Multi
- **Constrain** – Constrained/Unconstrained

FLP for Entering (new) vs Expansion Firm

- **Entering** a firm into a new market involves identifying the most suitable locations for new facilities, such as **retail stores** or **warehouses**.
- Firm **expansion** involves optimizing the placement of additional facilities to enhance an existing network of locations.

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Compositions of FLP

- In the practical world FLP meets with a combination of different problem characteristics as below. **Eg -:**
  - Discrete Competitive Facility Location Problems (DCFLP)
  - Discrete Competitive Facility Location Problems (DCFLP) for Entering Firm with - Single Objective
  - DCFLP for Firm Expansion (DCFLP/FE) –bi-objective
  - DCFLP/EF with constraints
  - Etc.

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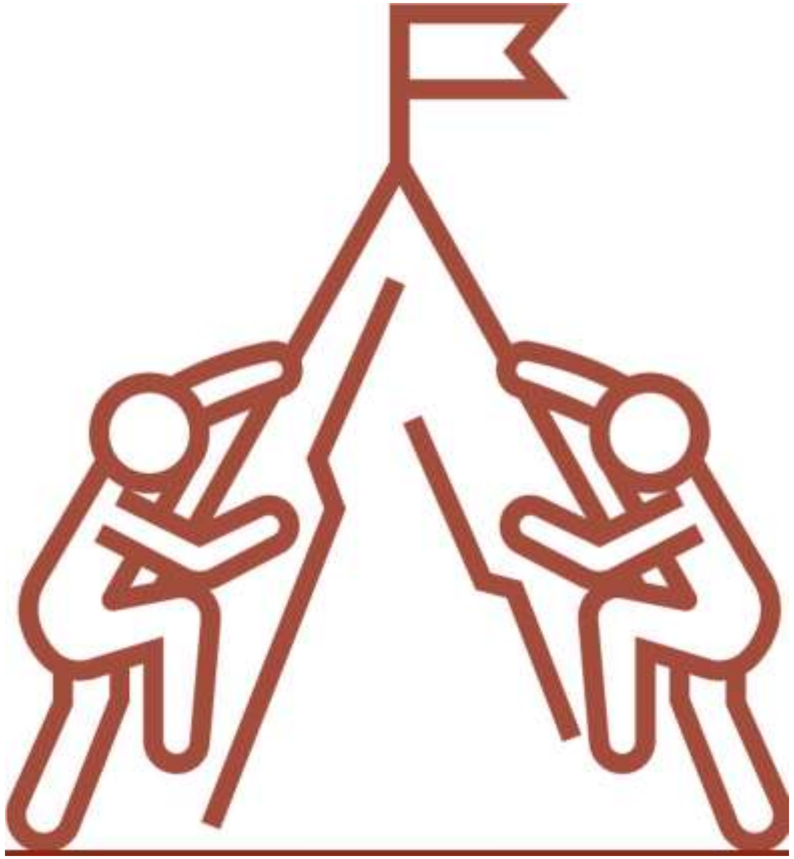
Competitive Facility Location Problems

- Competitive Facility Location Problems (CFLPs) focus on the strategic placement of facilities considering the presence of competitors.
- These problems analyze how facility locations can influence market share, customer capture, and overall competitive advantage.



Average Distance Factor

- The Average Distance Factor (ADF) is a metric used in facility location analysis to assess the average distance that customers must travel to reach a facility.
- It helps businesses understand accessibility and service efficiency. A lower ADF indicates better customer accessibility and potentially higher customer satisfaction, while a higher ADF can signify logistical challenges and increased transportation costs.
- By optimizing ADF, companies can enhance their competitive advantage by improving service levels and operational efficiency.

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ADF for Binary and Proportional Model

- **Binary Model**
  - Customers choose the nearest facility deterministically.
  - Lower ADF means better coverage and higher customer satisfaction.
- **Proportional Model**
  - Customers choose facilities probabilistically, with choices weighted by distance.
  - A **lower ADF** increases the likelihood of customers choosing nearby facilities.

- **Importance of ADF**
  - **Evaluate facility distribution** and **coverage**.
  - **Optimizes location decisions** for better customer service and operational efficiency.
  - Helps in **strategic planning** for public services, retail networks, and logistics by minimizing customer travel distances.

Average distance factor with square vs Circular shapes

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1. **State area** is given, and for a square, the side length s can be calculated as:

$$s = \sqrt{\text{Area (km}^2\text{)}}$$

2. The diagonal of the square is $\textbf{Diagonal} = s \times \sqrt{2}$, and the maximum distance from the capital would be half of this diagonal:

$$\text{Max Distance} = \frac{s \times \sqrt{2}}{2}$$

3. This distance is then treated as the "average distance factor."

Circular Area: For a circular shape, the distance from the center to the edge (i.e., the radius) is given by the formula $r = \sqrt{\frac{\text{Area}}{\pi}}$.

Average Distance Factor Square vs Circular Comparison

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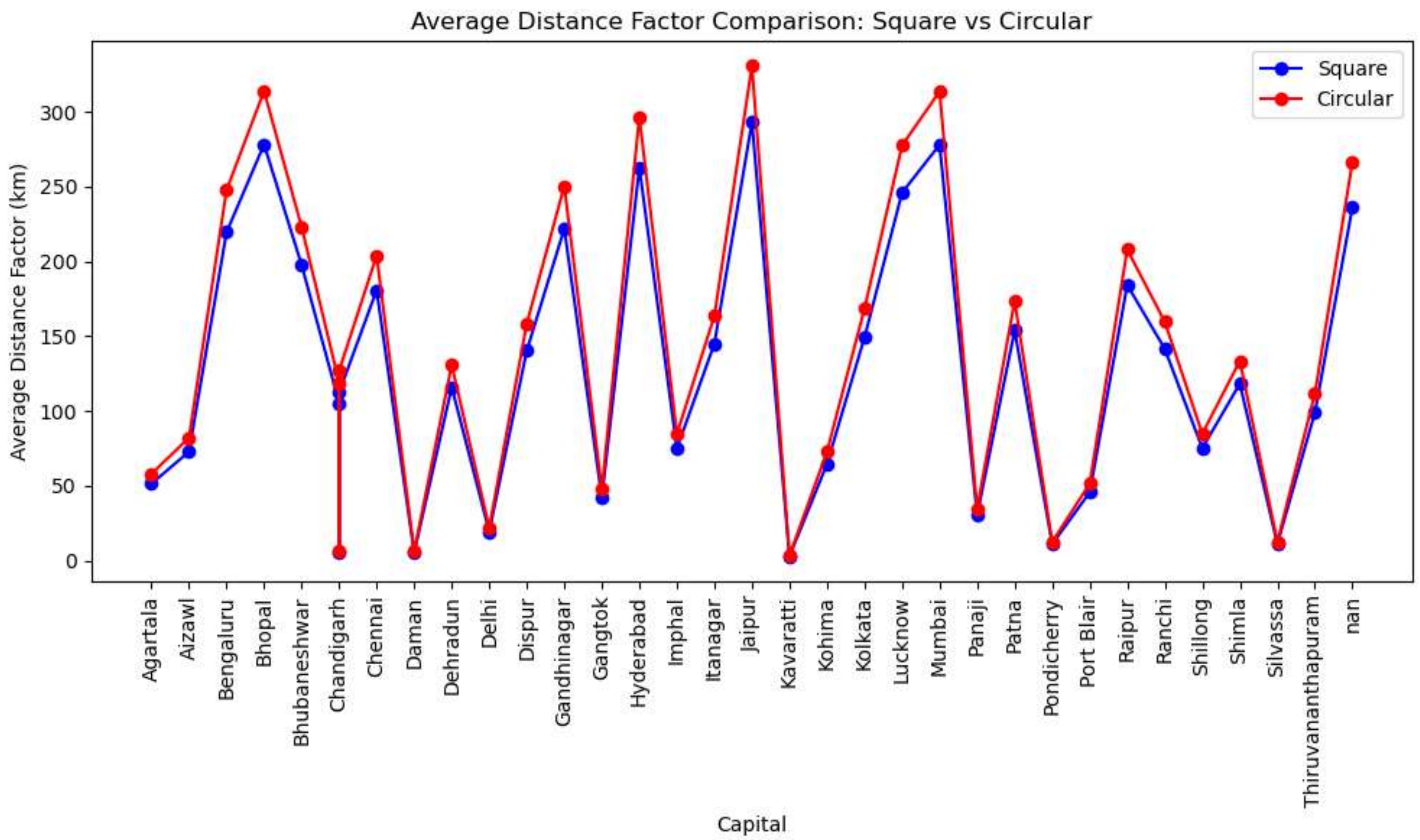

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Results Discussion – ADF with India state population dataset

- Average factor can define location identity over a given area.
- circular location could be given law average distance factor that square option under most of the time.
- Further ADF can be used for distance factors for customer behavioral models.

Customer Behavior Models in Facility Location Problems

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- Customer Behavior Models (CBM) play a crucial role in facility location problems as they help in
  - **understanding** how customers behave
  - **make decisions** regarding their **choice** of facilities.
- Main Classifications of CBM for FLP
  - Binary Model
  - Partially Binary Model
  - Proportional Model (Huff Model)
  - Pareto-Huff Model

Implication of Binary and Proportional Models over data set

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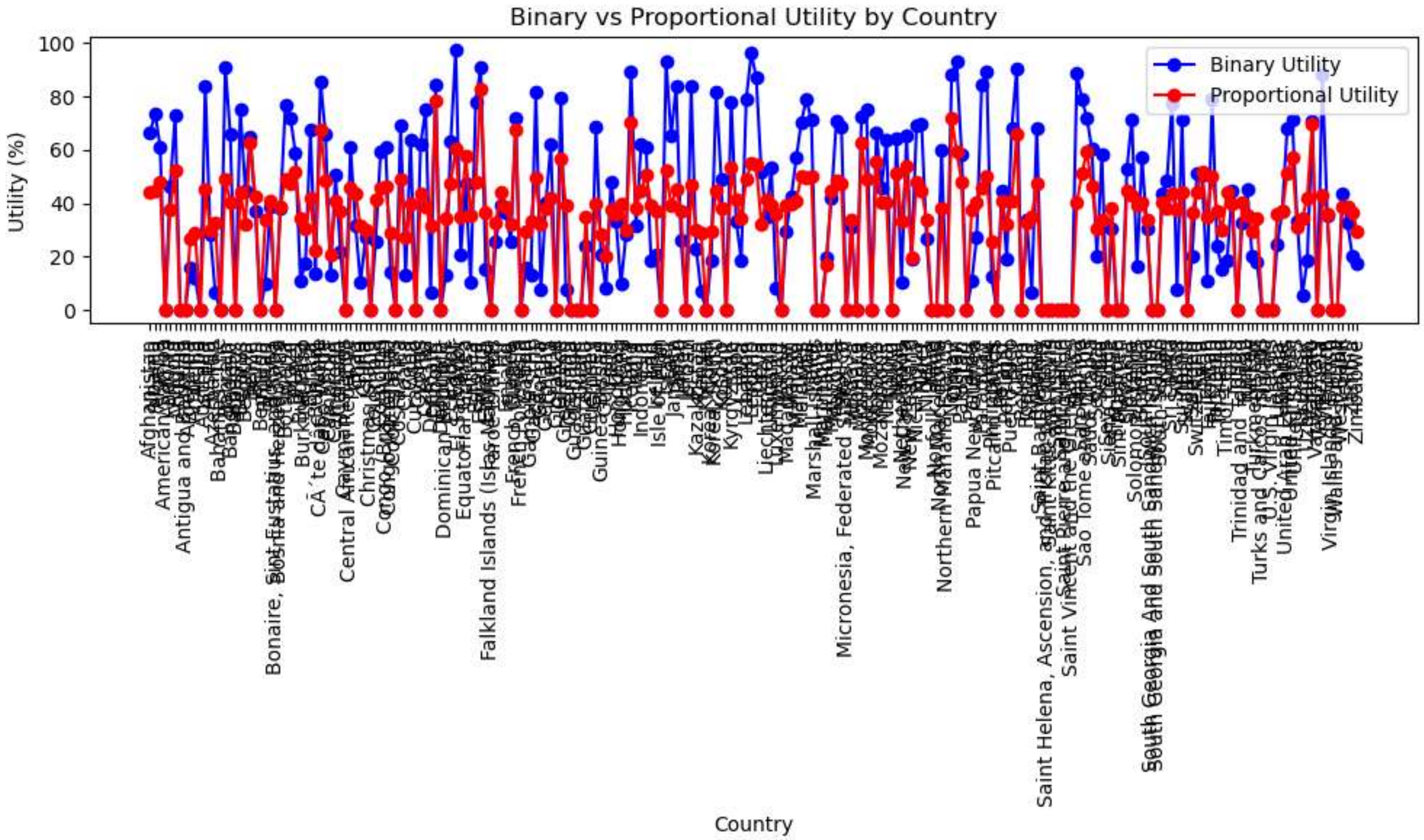

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Results and Discussion

- The binary model highlights where new hotels outperform existing ones.
- The proportional model offers a balanced view of customer preferences.

Binary and Proportional model implementation within Average Distance Factor

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Open new hotel – Average Distance Factor - Binary Model - Lithuania

Data Set – Data set with Lithuania hotels. each city consists of many hotels with GPS coordinates and city area, population etc.

	cityName	HotelName	Map	Population	Area (sq km)
1	Alytus	Dzukija Hotel	54.39582|24.04582	51353	48
2	Alytus	Hotel Ode	54.39784|24.03141	51353	48
3	Alytus	Hotel Senas Namas	54.39918|24.0462	51353	48
4	Alytus	Hotel Vaidila	54.39617|24.0499	51353	48
5	Alytus	Guest House Linas	54.39482|24.04129	51353	48
6	Anyksciai	Keturi Kalnai	55.52047|25.11584	10353	17.49
7	Anyksciai	Nykscio Namai	55.52059|25.1156	10353	17.49
8	Anyksciai	Spa Vilnius Anyk□ciai	55.51022|25.08501	10353	17.49
9	Anyksciai	Gradiali Anyksciai	55.49315|25.24346	10353	17.49
10	Anyksciai	o Turizmo Sodyba Geras	55.641876|25.273851	10353	17.49
11	Anyksciai	Pusu Takas	55.59769|25.05069	10353	17.49
12	Anyksciai	Helsinkis	3359|25.0925102233887	10353	17.49
13	Anyksciai	Sodyba Tarp Liepu	55.6417|25.26802	10353	17.49
14	Anyksciai	Day & Night	55.52544|25.10987	10353	17.49
15	Anyksciai	Raganu Nameliai	55.508|25.11261	10353	17.49
16	Anyksciai	Broniaus Sodyba	55.74189|25.45568	10353	17.49
17	Anyksciai	□uvienes Pa□iure	55.52811|25.28223	10353	17.49
18	Anyksciai	Aitvaras	46777|25.132682800293	10353	17.49
19	Anyksciai	Nijole ir Algimantas	3027|25.1109180450439	10353	17.49
20	Birzai	Tyla Hotel Birzai	56.1847|24.76618	12740	16.35
21	Birzai	anti viesbutis-restoranas	56.19685|24.7571	12740	16.35

Average Distance factor - Square vs Circular

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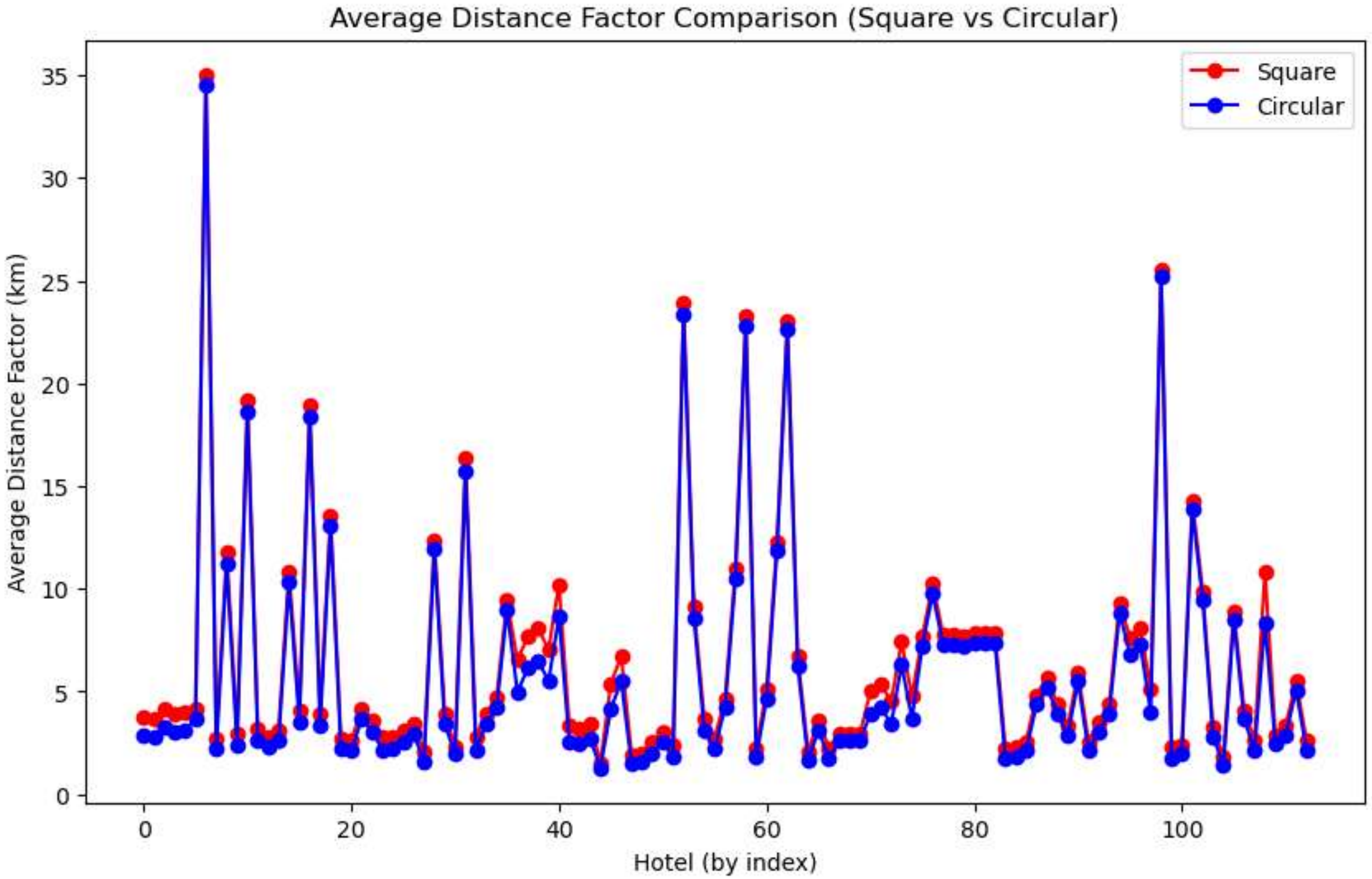

Attractiveness for New Location - Binary Model – (Considering Average Distance factors)

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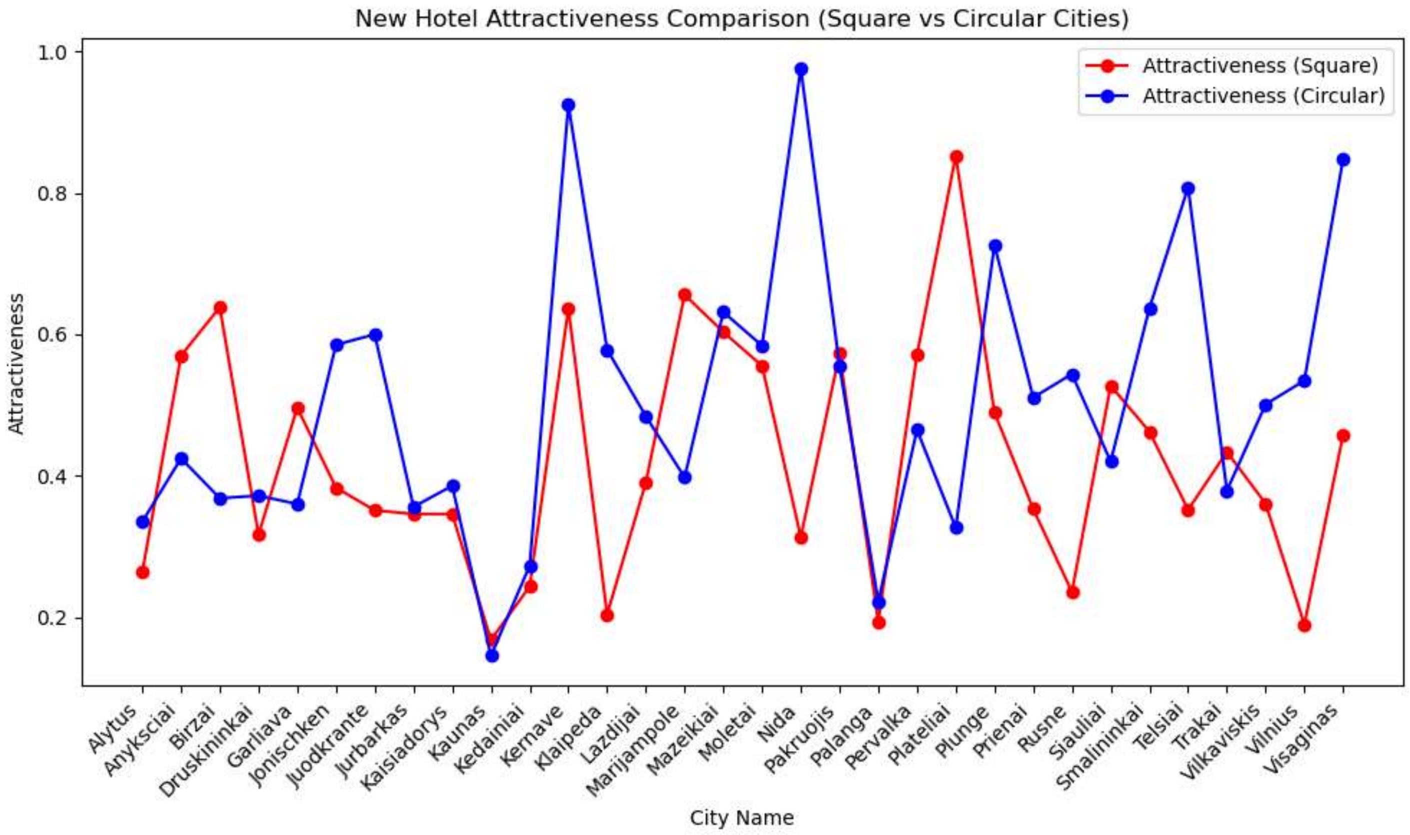

Attractiveness for New Location – Binary/Proportional Model – (Considering Average Distance factors)

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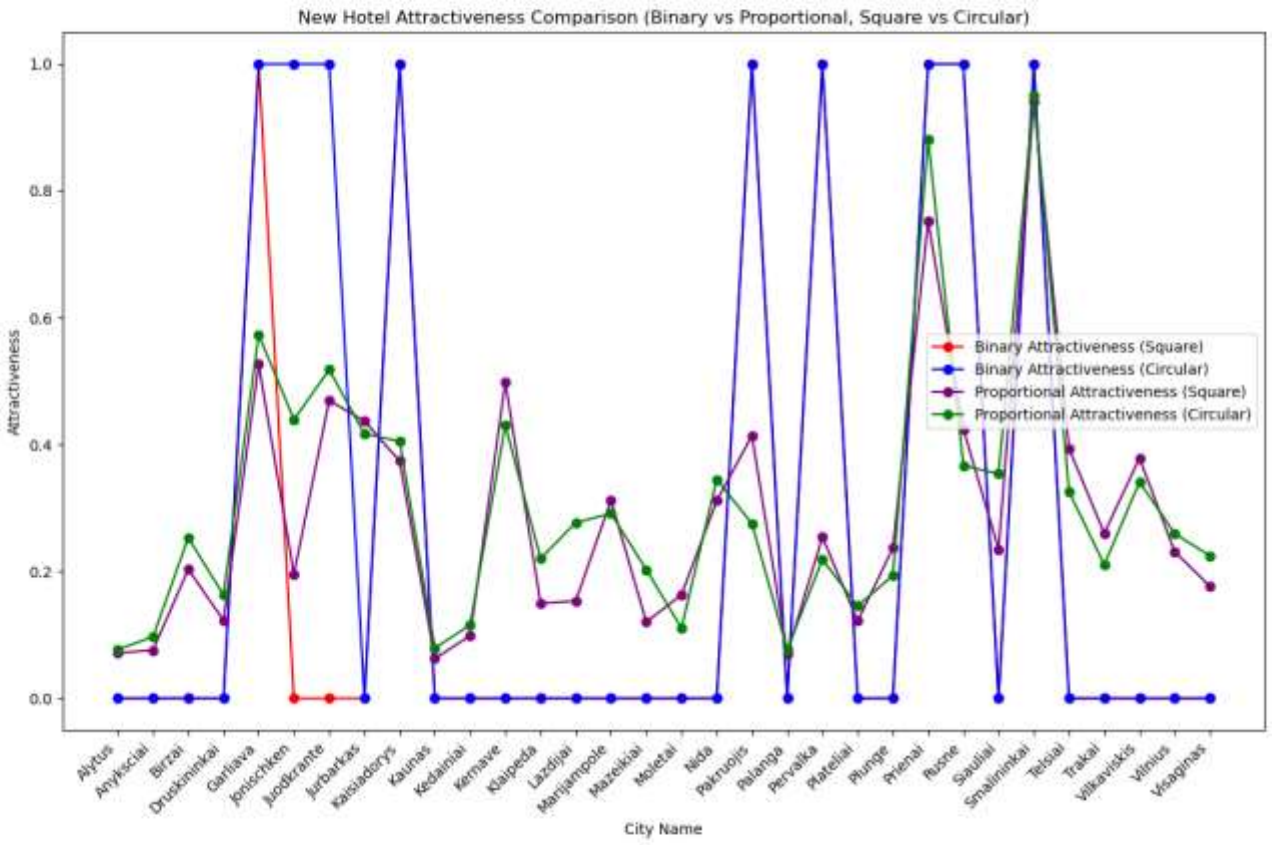

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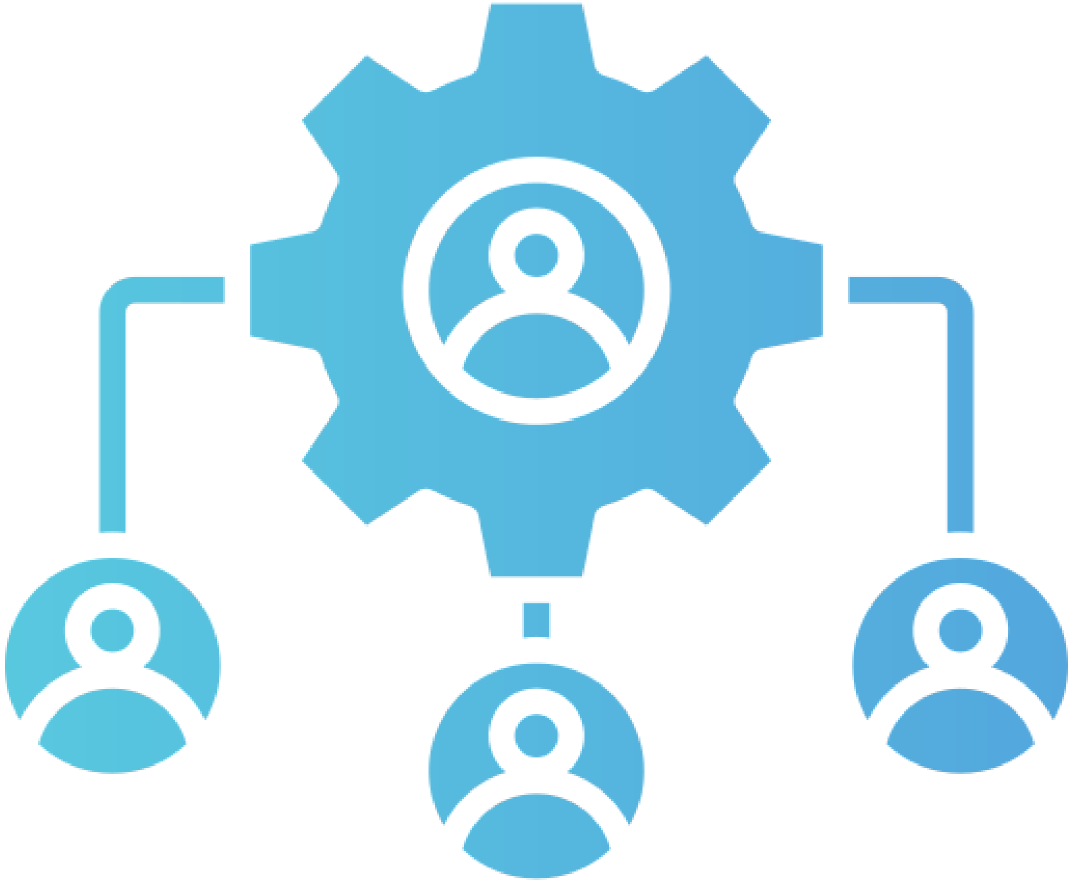
Results and Discussion

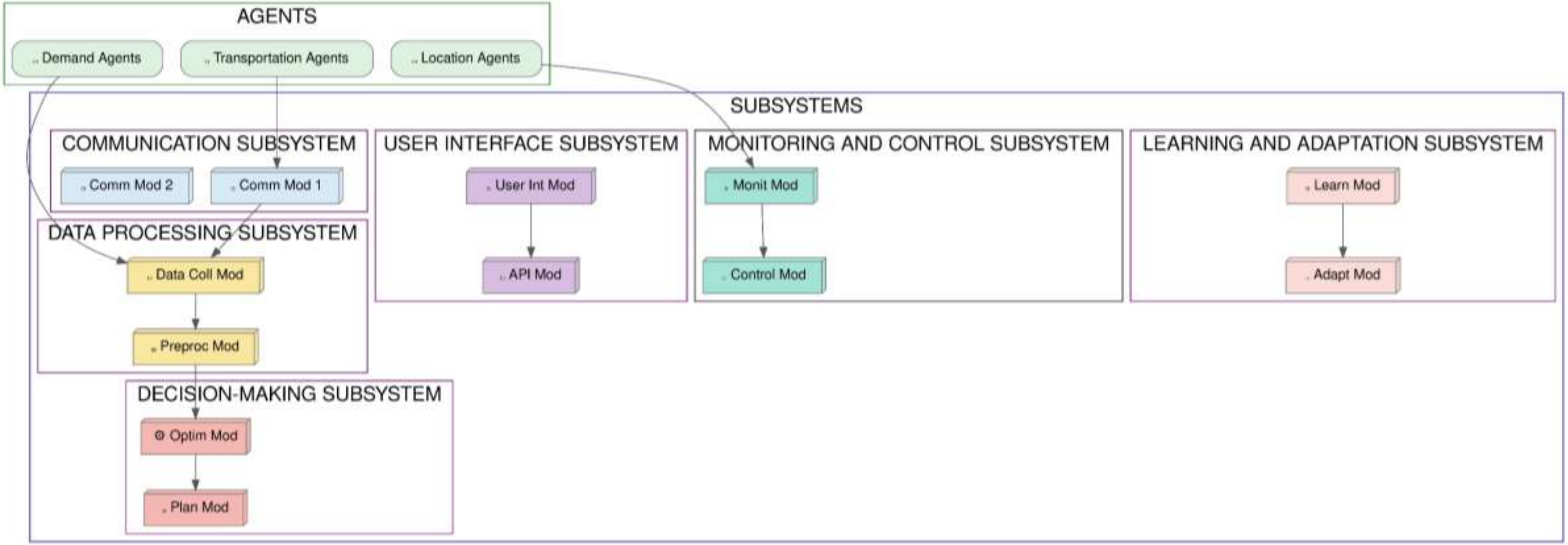
- The binary model is best for sharp, clear decisions, while the proportional model offers more stable, refined insights.
- Circular models may better capture city layouts for irregularly shaped cities, influencing attractiveness outcomes.

Multi-Agent System

- Multi-agent system (MAS) is a **core area of modern artificial intelligence** and their discipline.
- MAS is a subfield of **distributed Artificial Intelligence**.
- Since the MAS includes **multiple decision-making agents (computer applications)** in the shared environment, all those agents can be integrated and compromised to fulfill common goals.
- MAS can solve problems in a **distributed manner**.



MAS Architecture for FLP Agent, Modules and Sub-Systems



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Thank you