MANCHESTER SCHOOL OF ARCHITECTURE

Manchester Metropolitan University

Work Package 7: Urban Simulation & Modelling

Methodology Review report

D7.0 Report

March 2018

Contents

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Aims and Objectives

This report aims to form an investigative report in existing methodologies for the upcoming project tasks. The result of the study will inform subsequent research and design of innovative digital tools to inform the use of Autonomous Vehicles in areas of Manchester, UK.

Key Objectives:-

- Identify Methods of platooning concept transfer
- Investigate discourse analysis methods
- Conduct a research into existing competition digital models to come up with a method of creation
- Conduct a research into existing route selection / data mapping digital models to come up with a method of creation

Abbreviations

CAV	Connected Autonomous Vehicle
ABM	Agent Based Model
AV	Autonomous Vehicle

Introduction

Project tasks overview

As a member of the Synergy team, Manchester Metropolitan is tasked with delivering Work Package 7. The scope of the work consist of testing the platooning from a human and spatial perspective with the help and development of digital models as well as deep academic research.

Description of work to be undertaken is split down into four tasks consisting of:

•Task 1 - To expand the 'platooning' concept through concept transfer from ecological, social and biological perspectives.

•Task 2 - To undertake popular and expert discourse analysis to understand the landscape of AV integration on public roads in the UK.

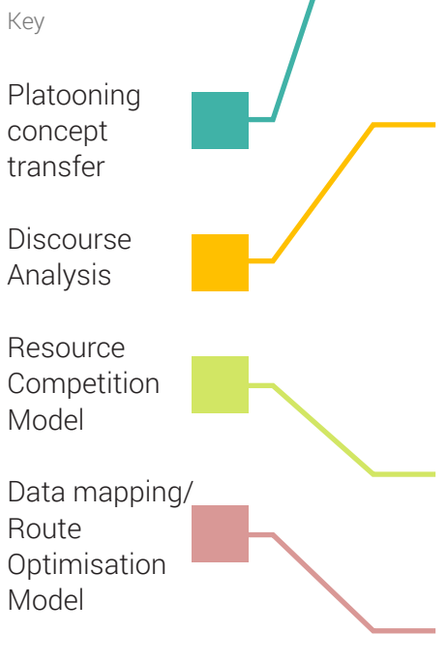
•Task 3 – To develop a digital simulation model testing the integration and disruptions resulting from introduction of AV into a competitive environment with other forms of transport services and passengers.

•Task 4 – To examine advantageous routes for the deployment of AV through data mapping.

This report aims to create a methodology for all four tasks and be used as a guide for the future steps of this project. Methodology is the systematic theoretical analysis of the methods applied to a field of study. The methods described within the report have their foundations in both academia and commercial sectors from a variety of disciplines and professions.

Executive Summary

A number of research methods have been outlined throughout the report. A breakdown of the methods for each task is listed below.



A) Platooning concept will be expanded by looking into four different fields, engineering, ecology, biology and social sciences. The Resource types will include:

1) Academic (journals, books etc)
2) Popular Media (news articles, documentaries etc)
3) Commercial (existing applications, products etc)

B) Discourse analysis is a general term for a number of approaches to analyse language and how it has been used to deliver the information. The levels of analysis will be: a textual level, a contextual level and an interpretive level. There will be:

1) Popular discourse analysis with focus on media
2) Expert discourse analysis with focus on academic literature and government documents

C) Resource Competition Model will be an Agent-Based Model study where the agents of CAV's compete with other modes of transportation for customers / resources.

D) Data Mapping and Route Optimisation model will seek to test the best environment for the deployment of CAV's.

Both models will draw inspiration from precedents that range from different model families, types and attributes.

1) Families:
   For the purpose of these tasks, three sub-categories have been selected for exploration. These are Agent-Based Simulation Models, Cellular Automata Models and Network Models.
2)Types:
   For task 3 + 4, the range of model types can vary from Foraging Models to Route Optimisation Models as phenomena explored change.
3)Attributes:
   These essentially describe the type of data to be inputted or outputted, the degree of random behaviour of agents and the way the model will run.

Task 1

Platooning Concept Transfer Methods

This study focuses on expanding the understanding of the concept of platooning and the potential efficiency it may bring to the autonomous vehicle (AV) area. The research will be contacted with both an inductive Research Approach and exploratory Research Design. Inductive in the sense that the report will seek to find answers in the form of platooning concept transfers and Exploratory as we wish to explore the subject area in depth.

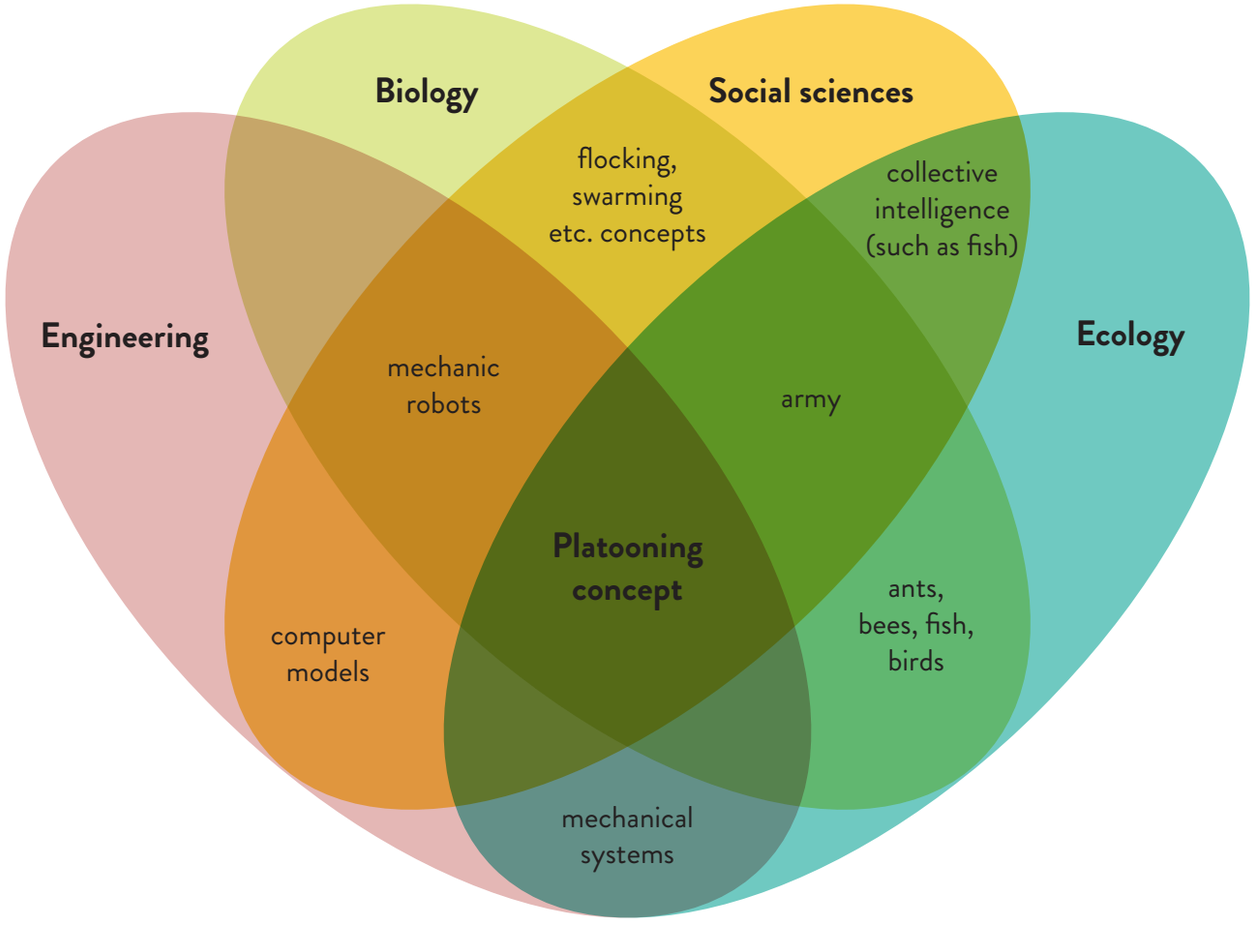
The variety of methods will be applied to four pre-identified disciplinary categories which includes:

A) Ecology : The study of living organism's interactions with other organisms or the physical environment.
B) Social sciences : Aspects relating to human society and / or its organisation
C) Biology : Relating to biology of living organisms
D) Engineering : The application of scientific and mathematical knowledge in the creation of mechanical systems.

The four disciplines serve as starting research points for the scope of knowledge contained within the platooning concept. Within each of the four categories there will be a detailed research to be undertaken that will involve a mixture of methods as reviewed below:

1)Archival Research
2)Case Study Analysis
3)Content Analysis
4)Library Research
5)Internet Research
6)Interviews
7)Media Research

Platooning concept can also be a product of other effects in these four disciplines. Examples include the notion of collective intelligence, flocking, swarming and other concepts. These will also be researched as part of the platooning concept report. The initially identified concepts / examples to be searched can be seen in the diagram below, split into the relevant disciplines they form a part of.



Resource Types

Having identified the research methods, there needs to be a clear distinction in the resource types. These are essentially the data to be collected / analysed for the purpose of understanding / exploring the platooning concept.

Academia

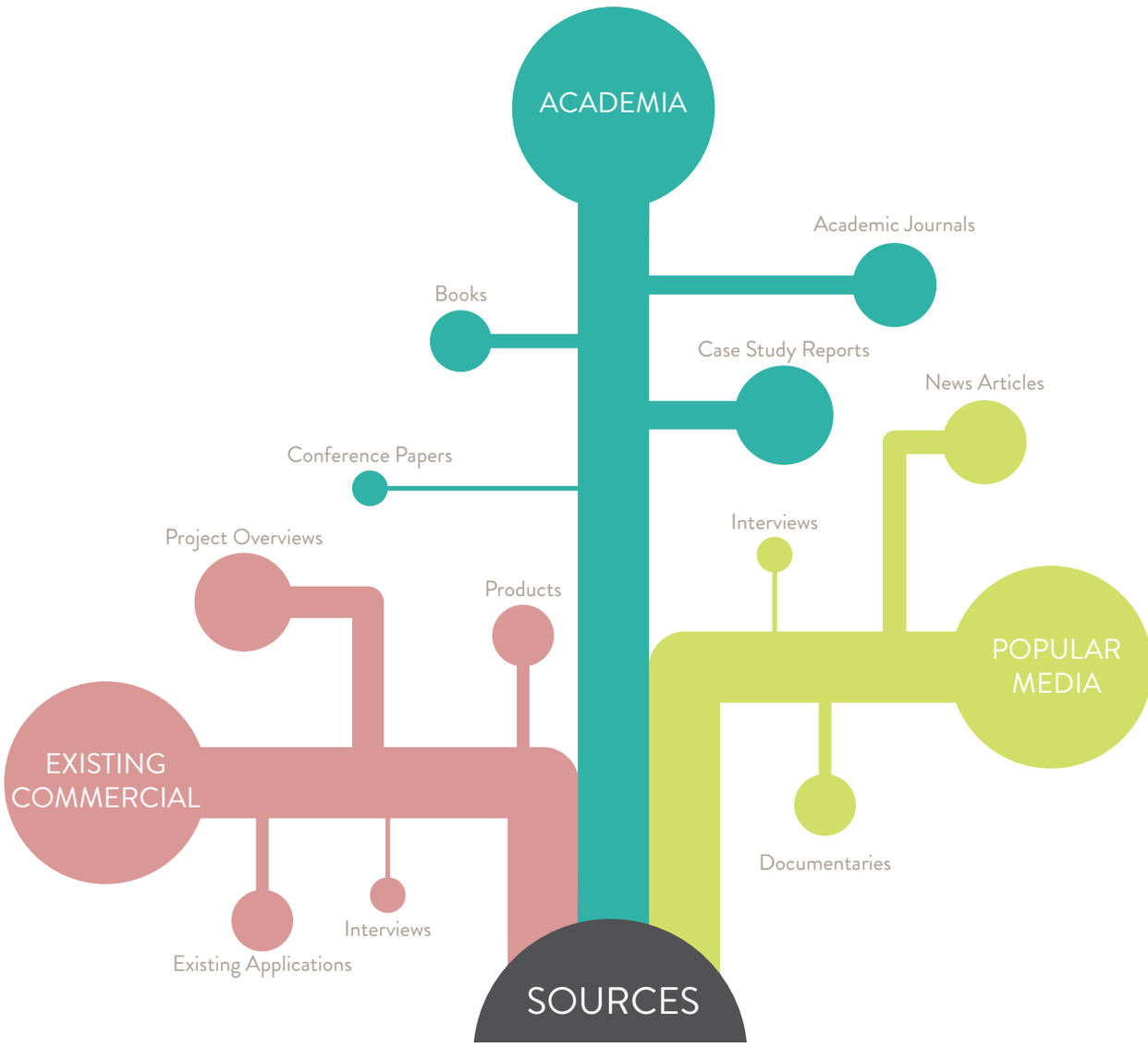
The first and most relevant category of resources for this report, falls in the realm of academia. These include a vast literature contained in Books, Case Study reports, Academic Journal Papers and Conference Papers. For this report, they will most likely form the majority of the resources as the platooning concept is mainly explored through Academia.

Popular Media

Popular Media consists of any information in the public realm in the form of news articles, interviews with experts and documentaries. These resources are mainly used to understand human perception on a subject thus the use of it in platooning concept transfer is limited.

Existing Commercial

The last resource area is existing commercial which look into innovations and information on the subject from a commercial stand point. This includes a look into ongoing projects, interviews with company officials, existing applications of concept in the commercial sector and any products that are based on the particular concept. Platooning concept from an engineering perspective, is mainly focused on optimising efficiency hence it is well suited for the commercial sector making it an interesting source.


ACADEMIA
Academic Journals
Books
Case Study Reports
News Articles
Conference Papers
Interviews
Project Overviews
Products
POPULAR MEDIA
EXISTING COMMERCIAL
Documentaries
Interviews
Existing Applications
SOURCES

Resource Weighting

The last part of the platooning concept methodology report needs to include a measure of resources to be viewed. These have been once again split into the 3 resource areas of academia, popular media and existing commercial.

All numbers of resources are estimated in accordance to time allocation and perceived usability. The weights may change in the course of the report writing depending on the research findings. A breakdown of the weighting numbers of resources to be viewed is listed below:

Academia

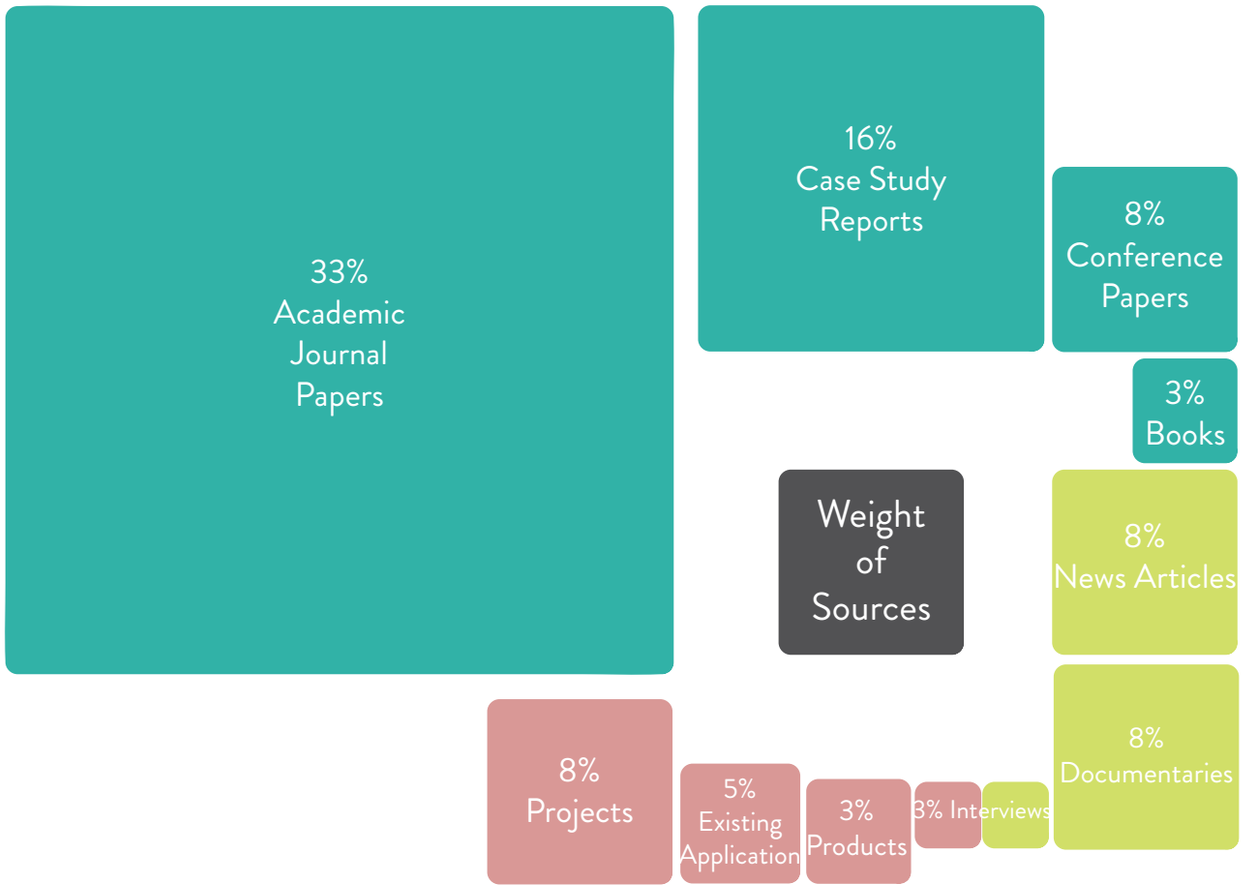
- 33% Academic Journal Papers
- 16% Case Study Reports
- 8% Conference Papers
- 3% Books

Popular Media

- 8% News Articles
- 8% Documentaries
- 1.6% Interview

Existing Commercial

- 8% Project Overviews
- 5% Existing Applications
- 3% Products
- 1.6% Interview


33%
Academic
Journal
Papers
16%
Case Study
Reports
8%
Conference
Papers
3%
Books
Weight
of
Sources
8%
News Articles
8%
Documentaries
8%
Projects
5%
Existing
Application
3%
Products
3% Interviews

Task 2
Discourse Analysis

This task is to undertake popular and expert discourse analysis to understand the landscape of AV integration on public roads in the UK.

Discourse analysis is a general term for a number of approaches to analyse language and how it has been used to deliver the information. Discourse analysis has been taken up in a variety of disciplines, such as social sciences, linguistics, human geography and others, each of which is subject to its own assumptions, dimensions of analysis, and methodologies.

The two parts of the analysis will be:

1) Popular discourse analysis with focus on how AVs have been portrayed in media. We will look at sources such as online articles and interviews, as well as people's responses (i.e. comments sections of such articles). We will also look at other forms of media, such as promotional videos and documentaries.

2) Expert discourse analysis of academic literature regarding AV integration and related policy documents and legislations.

From a sociological standpoint, **discourse** is defined as any practice by which individuals saturate reality with meaning.

In order to interpret discourse from a sociological standpoint, discourse must first be analysed from both a textual and a contextual approach. There are, therefore, three different levels of analysis: a textual level, a contextual level and an interpretive level.

Textual analysis: Characterization of discourse

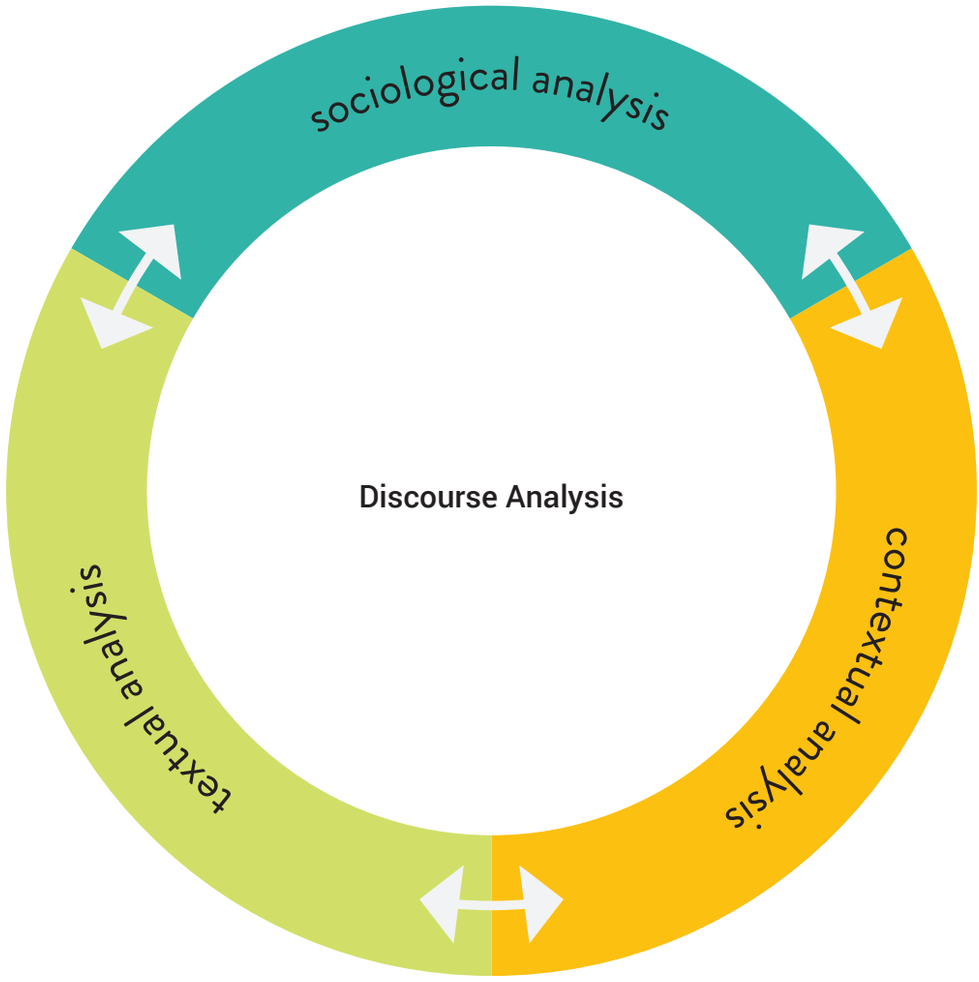
Textual analysis involves characterizing or determining the composition and structure of the discourse. The main two textual analysis techniques are content analysis and semiotic analysis.

Contextual analysis: Understanding discourse

The contextual level of analysis permits us to understand the meaning that discourse has for those who engage in it and therefore centers on how the subjects involved interpret the social situations.

Sociological analysis: (Sociological) explanation of discourse

The sociological interpretation of discourse involves making connections between the discourses analysed and the social space in which they have emerged.



Resource Types

Having identified the research methods, there needs to be a clear distinction in the resource types. These are essentially the data to be collected / analysed for the purpose of understanding / exploring scope of Autonomous Vehicle discourse analysis.

Academia

The first and most relevant category of resources for this report, falls in the realm of academia. These include a vast literature contained in Books, Case Study reports, Academic Journal Papers and Conference Papers. In the discourse analysis there will be an area covered by academia but only on the basis of technological advancement in CAV's.

Popular Media

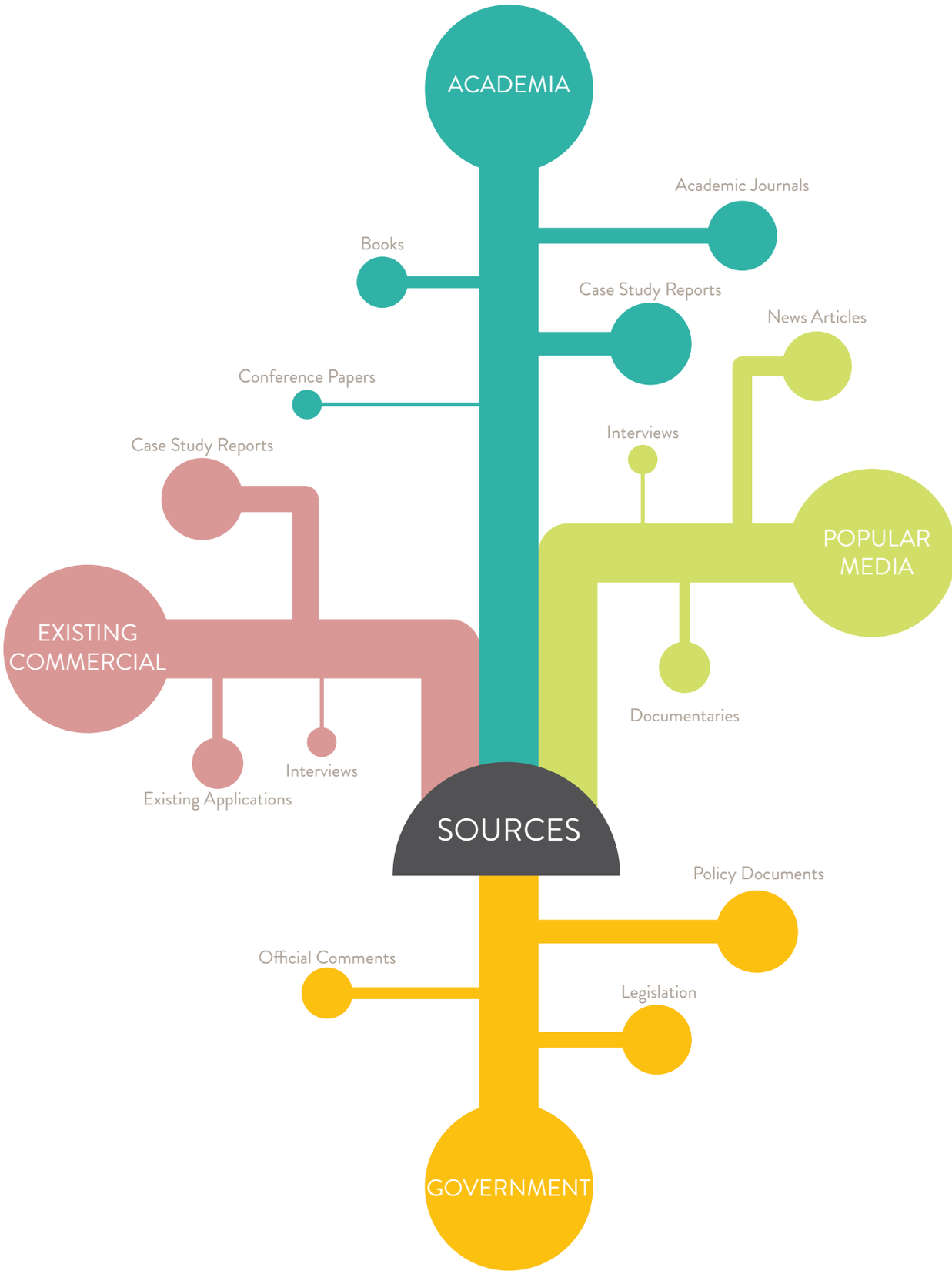
Popular Media consists of any information in the public realm in the form of news articles, interviews with experts and documentaries. These resources are mainly used to understand human perception and can indicate public opinion on Autonomous Vehicles.

Existing Commercial

Existing commercial which looks into innovations and information on the subject from a commercial stand point. This includes a look into case study reports, interviews with company officials and existing applications of Autonomous Vehicles in the commercial sector . What is expected to be gained in the commercial area of literature, is the level of existing integration of AV's in the real world today.

Government

The last area of research will be government policy, legislation and official comments on the subject. It will be in this sector that a look into current government stances on AV's will be understood.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Case Study Reports
POPULAR MEDIA
EXISTING COMMERCIAL
Documentaries
Interviews
Existing Applications
SOURCES
Policy Documents
Official Comments
Legislation
GOVERNMENT

Resource Weighting

The weighting of resources have been accumulated in this section of the report based on their resource type. The diagram on the right accurately displays the resource distribution in the four areas of academia, popular media, commercial and government.

All weighting of resources are estimated in accordance to time allocation and perceived usability. The numbers may change in the course of the report writing depending on the research findings. A breakdown of the weight of resources to be viewed is listed below:

Academia

- 16% Academic Journal Papers
- 8% Case Study Reports
- 8% Conference Papers
- 3% Books

Popular Media

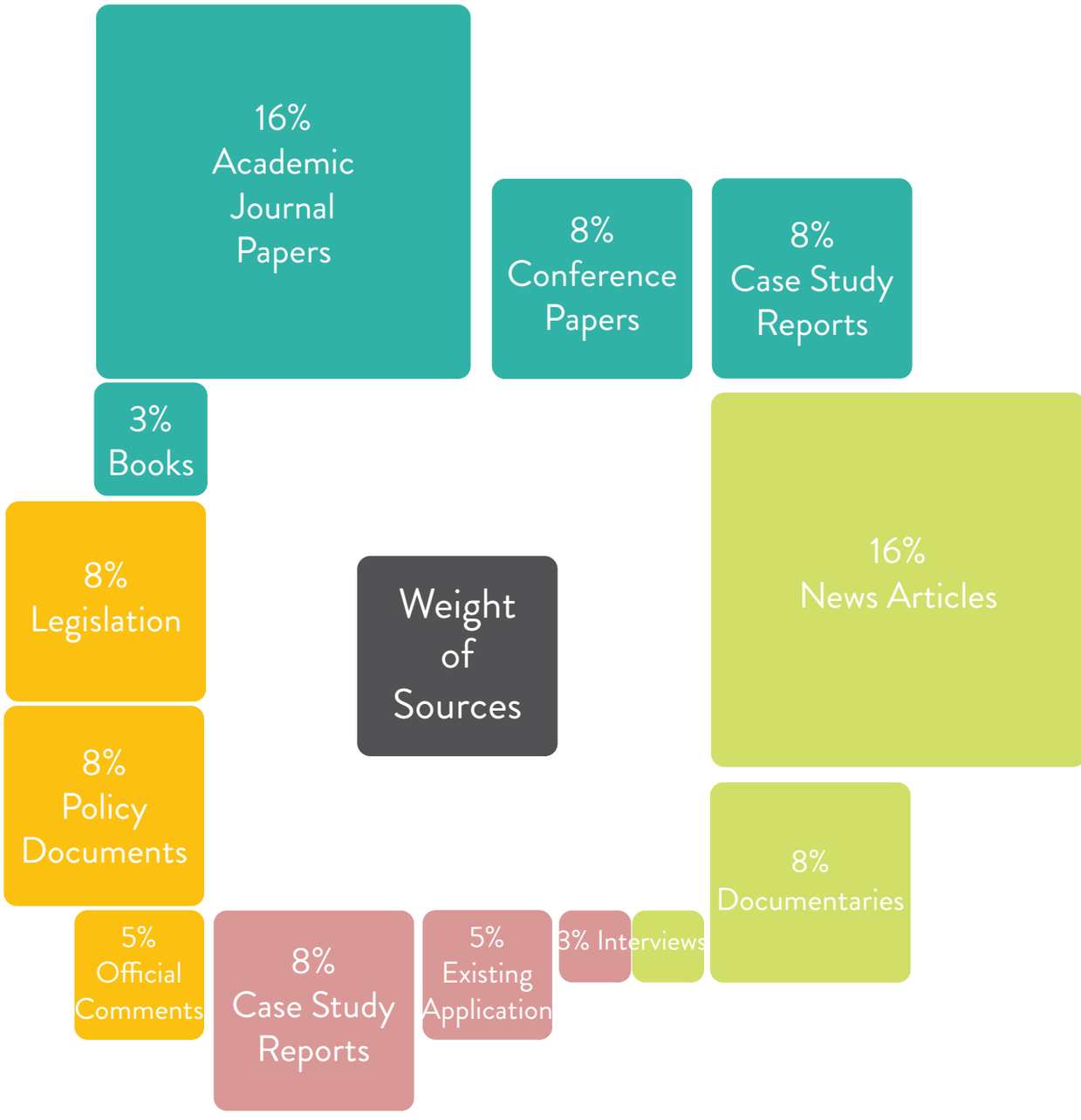
- 16% News Articles
- 8% Documentaries
- 1.6% Interview

Existing Commercial

- 8% Case Study Reports
- 5% Existing Applications
- 1.6% Interview

Gorvenment

- 8% Legislation Documents
- 8% Policy Documents
- 5% Official Comments


16%
Academic
Journal
Papers
8%
Conference
Papers
8%
Case Study
Reports
3%
Books
16%
News Articles
8%
Legislation
Weight
of
Sources
8%
Policy
Documents
8%
Documentaries
5%
Official
Comments
8%
Case Study
Reports
5%
Existing
Application
3% Interviews

Task 3 + Task 4

Simulative Service Competition Model + Route Selection Data Mapping

General Overview of task 3

The objective of Task 3 is to develop a digital simulation model testing the integration and disruptions resulting from introduction of AVs into a competitive environment with other forms of transport services and passengers.

In order to complete this task, we will develop an agent-based testable simulation of multiple transport systems including the existing ones (such as buses and trams) and new AV public transport system. The aim of the modelling is to test multiple scenarios to gain insight in the potential disruptive effects of new modes of transportations that can consecutively inform AV integration scenarios.

It will be an agent-based resource competition model. The behaviour of complex transport systems can be simulated bottom-up by modelling the behaviour and interactions of a large number of individual entities—agents (such as people and vehicles)—in the system. The high level of detail provided by data-driven agent-based models enables testing a range of scenarios and what-if questions, including the impact of infrastructure developments, adoption of new mobility and transport policies or changes in mobility services available.

Agent-based models and related terminology is further explained in the following sections.

General Overview of task 4

The objective of Task 4 is to examine advantageous routes for the deployment of AV with use of geospatial data.

AVs are capable of sensing its environment and navigating without human input and therefore data is crucial for deployment of AVs. Having access to live data and being able to make decisions informed by that data is advantageous for the AVs.

For this task we will map transport routes in a graph/network model and add geospatial data to it. The data will be used to optimise route selection for the AVs and identify potential areas where the implementation of AVs would be most beneficial and effective.

What is an Agent-Based Model

ABMs is a class of models that represent objects on individualistic level. Those effects can be observed through space and time. ABMs are bottom-up models that can generate emergent patterns and behaviours in a more aggregate level. The benefits of ABM over other modeling techniques are:

1) ABM captures emergent phenomena
2) ABM provides a natural description of a system
3) ABM is flexible

Structure of Agent-Based Model

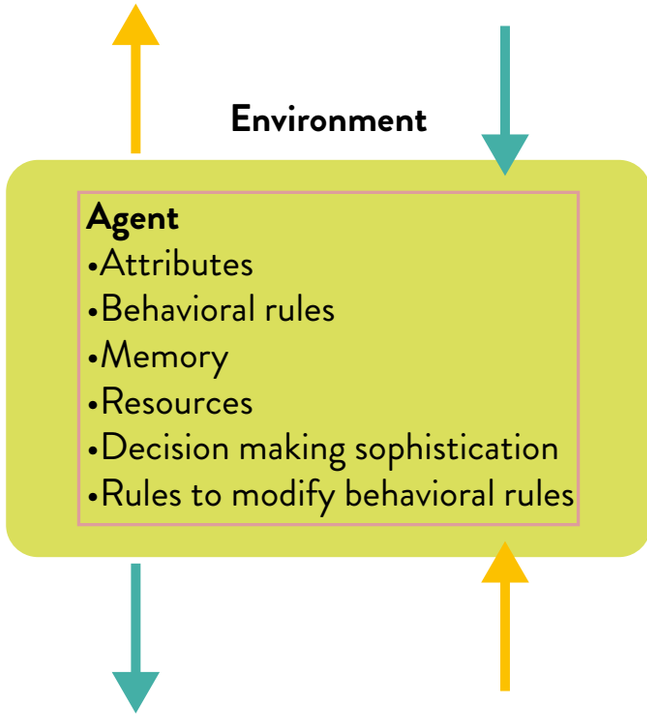
Agent-based modelling is a style of modelling in which individuals and their interaction with each other and their environment are explicitly represented.

A typical agent-based model has three elements:

1) A set of agents, their attributes and behaviours
2) A set of agent relationships and methods of interaction: An underlying topology of connectedness defines how and with whom agents interact
3) The agents' environment: Agents interact with their environment in addition to other agents

Agents

In agent-based modelling, a system is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. In any ABM, an agent is a self-contained, modular, and uniquely identifiable individual. An agent is autonomous and self-directed. An agent can function independently in its environment and in its interactions with other agents, at least over a limited range of situations that are of interest in the model. An agent is social having dynamic interactions with other agents that influence its behaviour. Agents have protocols for interaction with other agents, such as for communication, movement and contention for space, the capability to respond to the environment, and others. Agents have the ability to recognize and distinguish the traits of other agents.


Environment
Agent
•Attributes
•Behavioral rules
•Memory
•Resources
•Decision making sophistication
•Rules to modify behavioral rules

Simulation Model Overview

In order to understand what type of model to develop, there is a need to look into model families, types and attributes. Each of them exist on separate scales within the model and determine both the inputs needed and the outputs generated by the model.

Model Family

The tasks require the creation of a competition model. As the model will consist of autonomous agents, it falls within the Agent-Based model family. As explained in the previous pages of this report, an agent-based model is an overview of all model families consisting of interacting agents. For the purpose of these tasks, three sub-categories have been selected for exploration. These are Agent-Based Simulation Models, Cellular Automata Models and Network Models..

Model Type

The middle scale of a model consists of its purpose / core agent behaviour. These types describe the both the subject explored in the model and the agent objective. For task 3 + 4, the range of model types can vary from Foraging Models to Route Optimisation Models as phenomena explored change. The former explores CAV's behaviour in finding / picking up customers and the latter explores CAV's movement behaviour to interpret the best routes based on a number of assumptions.

Model Attributes

The last part of a model to be explored are its attributes. These essentially describe the type of data to be inputted or outputted, the degree of random behaviour of agents and the way the model will run. For example, A stochastic search model enables a degree of randomness in agent behaviour while deterministic modelling will always have the same output if given the same input.

COMPUTATIONAL MODEL TYPES

ATTRIBUTES

- Stochastic
- Deterministic
- Continuous
- Discrete
- Dymanic System
- Local
- Distributed

MODEL FAMILY

- Agent-Based Simulation Model
- Cellular Automata Model
- Network Model

Model Family

There needs to be a clear understanding of what model families have been considered for the completion of Tasks 3 & 4. A description of each is listed bellow:

Agent-Based Simulation Models

A family of models that is founded on the representation of objects at an elemental or individualistic level. The behaviour of these objects, also known as agents, are reflected in the model through space and time. An agent-based model operates from the bottom-up generating emergent patterns at more aggregate levels.

Cellular Automata

A class of agent-based models formed of either 2 dimensional or 3 dimensional lattice of cells where each cell depicts an individual agent. Each cell can have a range of states that can be influenced at each step of time by its neighbouring cells based on a range of preset rules. The focus in this type of agent-based modelling is the emergence of spatial patterns through time.

Network Model

The network model is a type of database model. It is created to understand the connection between the different agents. The most distinguishing feature is the nodes representing the agents and the edges connecting them representing the relationship type that exists between the two nodes.

Model Type

Having identified the model families that will be investigated / used for the tasks, it is time to identify the type of model. The following types are close to what the tasks 3 & 4 require thus concepts will be taken from them:

Foraging Model

In a foraging model, the behaviour of an animal / agent searching for food is modelled. The animal wants to gain the most resources for the lowest cost (in terms of time / energy spend) during foraging, so that it can optimise its action. The model effectively serves at predicting / optimising the foraging behaviour of an agent. This is controlled by the constraints set to the agent by the modeller and the number of resources inputted.

Traffic Simulation

These are models created for the planning, designing and operation of traffic. Their usefulness can be applied to a microscopic, macroscopic and sometimes mesoscopic perspective level. In transportation planning the focus stems on the impact of urban development on the performance of the transportation infrastructure. On the other hand, modeling of transportation system operations and design effectively models a much smaller scale of the system. Its focus is on the efficiency of a specific corridor or junction, lane type or signal timing. While models can specialized to a specific scale of operation, certain models have the capability to model both to some degree.

Resource Competition

This type of model pits two or more agents against each other in an attempt to see who will survive / gather the most amount of resources in a given time. It serves the purpose of understanding which agents have an edge given the specific assumptions assigned to them and the state of the environment. This model's complexity can vary as the number of different resources appealing to different agents as well as some agents being a resource changes.

Route Assigning

Route assignment, route choice, or traffic assignment concerns the selection of routes (alternative called paths) between origins and destinations in transportation networks. These can be used

to look at how many users are estimated to be on a given route at a given time and their preferred mode of transportation as to better allocate routes to other type of users such as private car users vs bus users.

Route Optimisation

Stemming from the travelling salesman problem, this type of model seeks to find the most optimal route taken to minimise journey time for the agent. For example, if an agent needs to make 5 checkpoints at different location around a given space, what order will he approach the checkpoints as to travel the shortest distance.

Swarming

Swarm behaviour or swarming model is the attempt to model agents following simple rules. The self organisation of individual agents creates an emergent pattern when viewed at a higher scale. This type of model seeks to test the notion of collective intelligence / behaviour exhibited by single near-zero intelligence agents.

Model Attributes

The final part of model identification is its attributes. These are primarily to distinguish the data inputs and outputs and are explained below:

Stochastic
Stochastic modelling indicates the existence of a random variable within a system. It is mainly used to estimate the probability of the different range of outcomes from the same starting scenario.

Deterministic
Deterministic models rule out possibilities of random variables with the outcomes precisely determined through known relationships. The only way to get a different output is to change the initial state.

Continuous
In a continuous system model, the state variables of agents change constantly with time. It is the modelling of a physical system that continuously tracks system response according to a set of equations.

Discrete
Discrete system simulation has state variables change at discrete points in time only. The operation of the system is modelled as a sequence of events occurring at particular instances in time marking the change in the system.

Dynamic System Simulation
Dynamic Simulation is the use of a computer program to model the time varying behaviour of a system.

Local
A local system model is essentially a model run by one machine with no communication / input from other computers on a network.

Distributed
A distributed system is a model in which components located on network computers communicate and coordinate their actions by passing messages. They co-operate to achieve a common goal.

Concepts Taken

Having identified the research methods, there needs to be a clear distinction in the resource types. These are essentially the data to be collected / analysed for the purpose of understanding / exploring scope of Autonomous Vehicle discourse analysis.

Foraging

Foraging concept for AV's centres around the identification and collection of people from various points on a map.

Stops

This part relates to the infrastructural concerns for the deployment of AV's, where and when they can stop to pick up.

Transport Modes

In the competition model, there will be a need to include a variety of competing transport modes (bus, tram, AVs..).

Customer as Resource

Every agent will be collecting resources within the model and in this case, the resources are transport customers.

Infrastructure / Route

Every agent will require its specific / shared infrastructure to function in as well as, in some cases, designated routes.

Agent Count

The different agents will be deployed within the model at different counts. This depends on the infrastructural capabilities,

Competition

Each type of agents will be competing against other types of agents in order to test the impact they may have on another.

Network Connection

CAV's are effectively connected to a larger grid of communication which may also need modeling.

CONCEPTS TAKEN

AGENTS | ACTIONS | ENVIRONMENT | INPUT | OUTPUT

Foraging

Stops

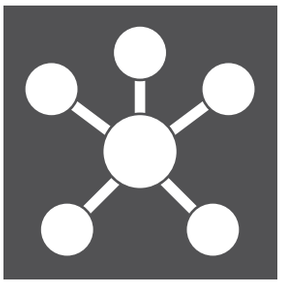
Transport Modes

Customer as Resource

Infrastructure / Route

Agent Count

Competition



Network Connection

Conclusion

Platooning Concept

The research will be contacted with both an inductive Research Approach and exploratory Research Design. Inductive in the sense that the report will seek to find answers in the form of platooning concept transfers and Exploratory as we wish to explore the subject area in depth. This will be done by looking into four different fields: engineering, ecology, biology and social sciences.

In each of these field, resources ranging from different types will be assessed and a concepts taken.

The Resource types will include:

1) Academic (journals, books etc)
2) Popular Media (news articles, documentaries etc)
3) Commercial (existing applications, products etc)

A full breakdown of the weighting of the resources is given in the platooning concept part of the report as well as a range of initial readings.

Discourse Analysis

There will be two parts of discourse analysis:

1) Popular discourse analysis with focus on how AVs have been portrayed in media
2) Expert discourse analysis of academic literature regarding AV integration and related policy documents and legislations

Simulative Service Competition Model + Route Selection Data Mapping

Resource Competition Model will be an Agent-Based Model study where the agents of CAV's compete with other modes of transportation for customers / resources.

Data Mapping and Route Optimisation model will seek to test the best environment for the deployment of CAV's.

Both models will draw inspiration from precedents that range from different model families, types and attributes.

1) Families:

For the purpose of these tasks, three sub-categories have been selected for exploration. These are Agent-Based Simulation Models, Cellular Automata Models and Network Models..

2)Types:

For task 3 + 4, the range of model types can vary from Foraging Models to Route Optimisation Models as phenomena explored change. These Types include:

1)Foraging Model
2)Traffic Simulation
3)Resource Competition
4)Route Assigning
5)Route Optimisation
6)Swarming

3)Attributes:

These essentially describe the type of data to be inputted or outputted, the degree of random behaviour of agents and the way the model will run. They are as follows:

1)Stochastic
2)Deterministic
3)Continuous
4)Discrete
5)Dynamic System Simulation
6)Local
7)Distributed

Concepts taken from these model precedents will be explored and used in the creation of task 3 & 4 models. So far, concepts identified are as follows:

1)Foraging
2)Stops
3)Transport Modes
4)Customer as Resource
5)Infrastructure / Route
6)Agent Count
7)Competition
8)Network Connection

A full breakdown of each of the family, types, attributes and concepts can be viewed at the task 3 & 4 part of the report.

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Synergy