



Week 7

Trieste and Mobility: *Mobility Asymmetry Matrices*

Daniel Carmody, Sadegh (Sadi) Sabouri

11.S951

Senseable City: Data and Analytics

March 18

IMPORTANT QUESTIONS TO ASK

- Where is public transit failing its riders?
- How many hours are wasted commuting when using modes of transport other than personal vehicles?
- How can city planners identify and prioritize the most important trips/routes to fix?



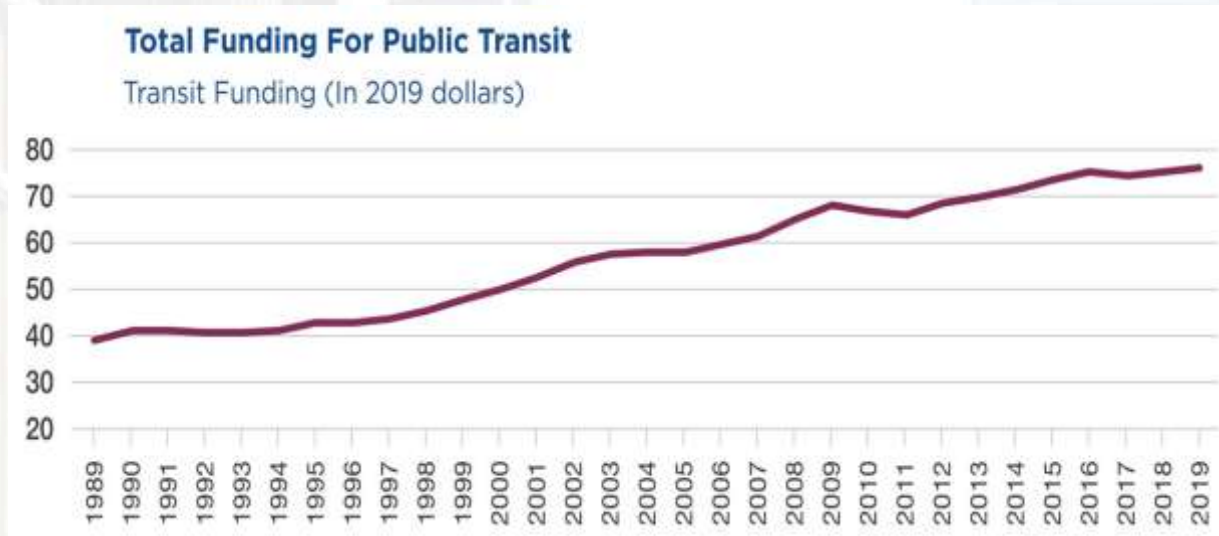
PUBLIC TRANSIT ROLE IN AN EFFICIENT TRANSPORTATION SYSTEM

- ❖ Traffic congestion
- ❖ Parking congestion
- ❖ Pollution emissions
- ❖ Excessive energy consumption
- ❖ Traffic accidents
- ❖ Rising fuel prices
- ❖ Rising roadway expansion costs
- ❖ Aging population
- ❖ Mobility for non-drivers

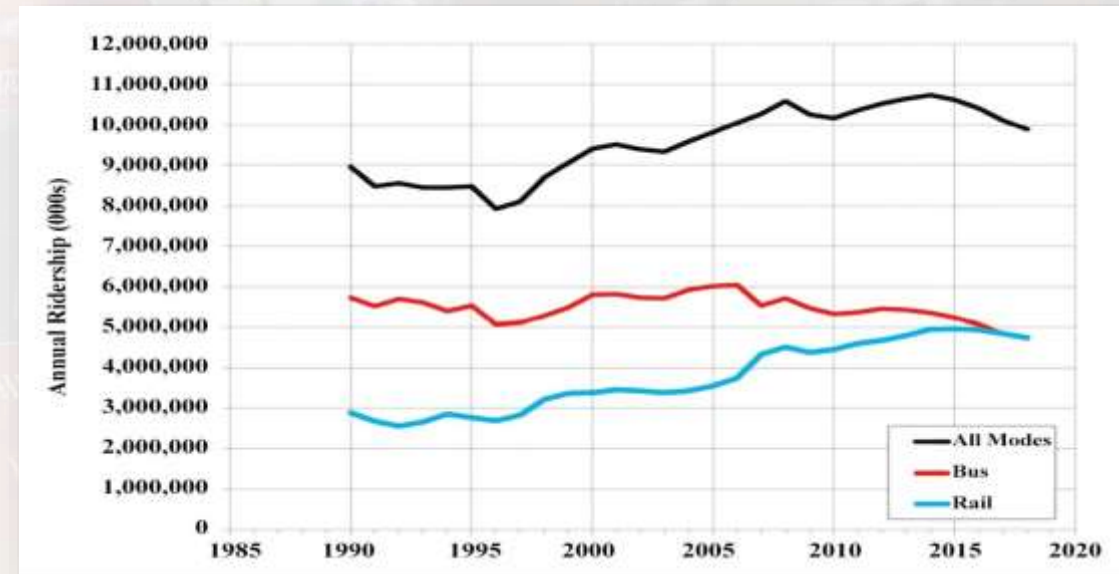
CITY	CONSTRUCTION COST PER SQUARE FOOT		CONSTRUCTION COST PER PARKING SPACE	
	UNDERGROUND \$/SQ FT (1)	ABOVEGROUND \$/SQ FT (2)	UNDERGROUND \$/SPACE (3) = (1) x 330	ABOVEGROUND \$/SPACE (4) = (2) x 330
Boston	\$95	\$75	\$31,000	\$25,000
Chicago	\$110	\$88	\$36,000	\$29,000
Denver	\$78	\$55	\$26,000	\$18,000
Honolulu	\$145	\$75	\$48,000	\$25,000
Las Vegas	\$105	\$68	\$35,000	\$22,000
Los Angeles	\$108	\$83	\$35,000	\$27,000
New York	\$105	\$85	\$35,000	\$28,000
Phoenix	\$80	\$53	\$26,000	\$17,000
Portland	\$105	\$78	\$35,000	\$26,000
San Francisco	\$115	\$88	\$38,000	\$29,000
Seattle	\$105	\$75	\$35,000	\$25,000
Washington, DC	\$88	\$68	\$29,000	\$22,000
Average	\$103	\$74	\$34,000	\$24,000

Source: Shoup, 2021. Quick review of his findings at [this link](#)

FALLING TRANSIT RIDERSHIP POSES AN 'EMERGENCY' FOR CITIES



Source: APTA Fact Book Analysis 2021

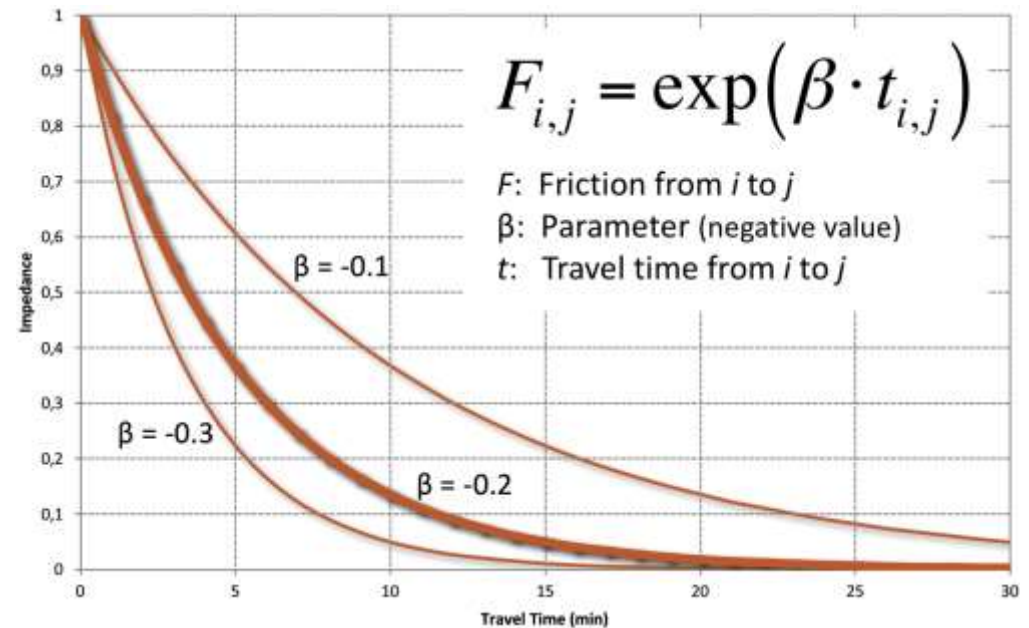


Source: National Transit Database

IMPORTANT TERMINOLOGIES

- ❖ Skim matrix (a.k.a network skimming):
provides impedances between locations/zones/neighborhoods

Describes how difficult it is to get from one place to another place. Commonly calculated as travel time, distance, costs, or a combination thereof called generalized costs



Source: <https://tfresource.org/topics/Impedance.html>

IMPORTANT TERMINOLOGIES

❖ Highway Skims

- Can be simple 'generalized cost' between each OD zone pair or complex taking into account single-occupancy vehicles, shared-ride 2,3+, time of the day (peak vs. non-peak hours)

❖ Transit Skims

- Attributes to consider: travel time, route fare, schedule, headway, speed, etc.

IMPORTANT TERMINOLOGIES

❖ Traffic Analysis Zone (TAZ)

- A special area delineated by state and/or local transportation officials for tabulating traffic-related data.
- These TAZs (which also stands for travel, transportation, or traffic analysis zones) may have several uses, depending on how a travel model is structured, including: storing information about the people and places in each zone, serving as origins and destinations of trips, and calculating travel times between (and within) zones.

Source: tfresource.com

IMPORTANT TERMINOLOGIES

❖ Travel Demand Modeling/Forecasting

- Travel Demand Forecasting is the process used to predict travel behavior and resulting demand for a specific future time frame, based on assumptions dealing with landuse, the number and character of tripmakers, and the nature of the transportation system.

Source: [CDOT](#)

- How many trips will be made in the future?
- Which transportation systems will become congested in the future?
- How much ridership will a new transportation service attract?

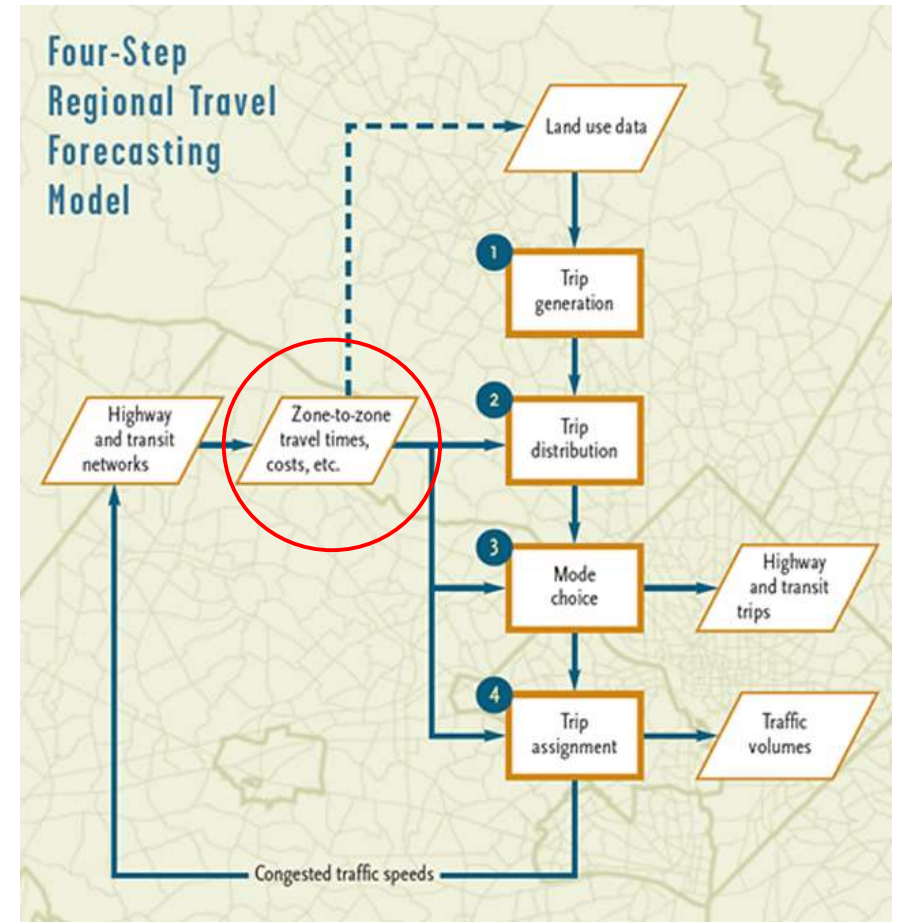
IMPORTANT TERMINOLOGIES

❖ Travel Demand Modeling/Forecasting

- Four-Step Travel Model
- Activity-Based Model

❖ Main Sources of Data

- Household Travel Survey
- Transportation Metrics Providers



Source: [MWCog](#)

TRANSPORTATION METRICS SERVICE



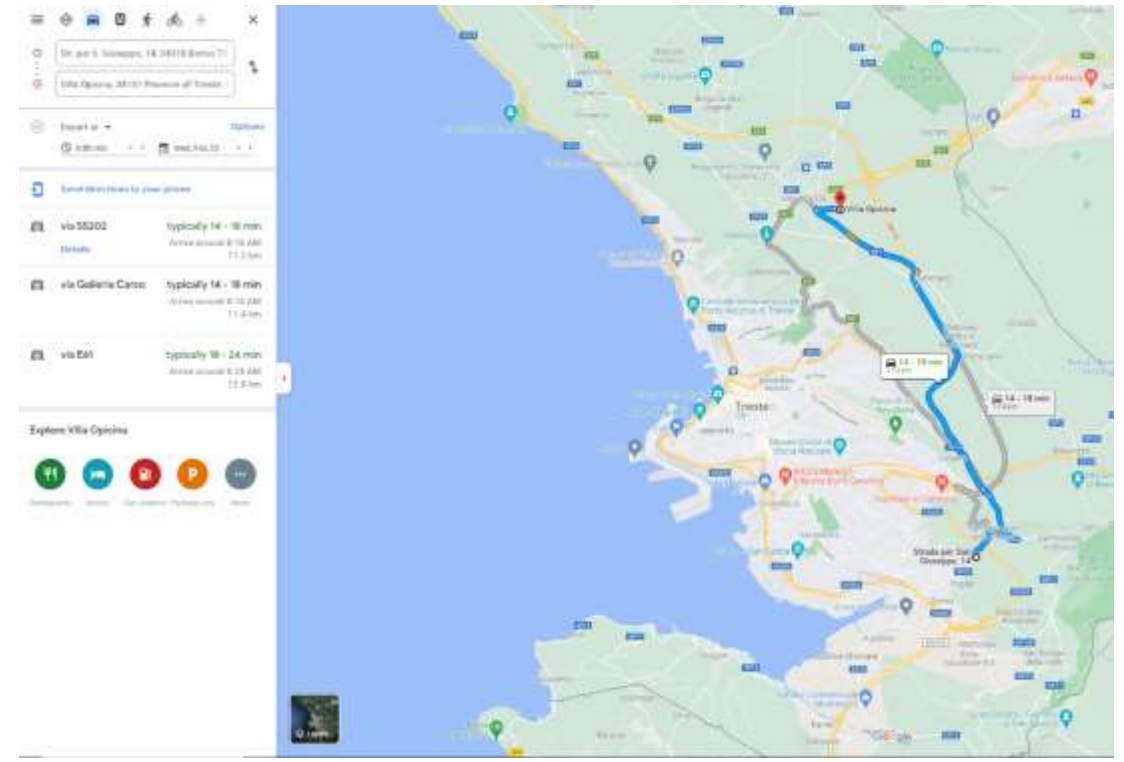
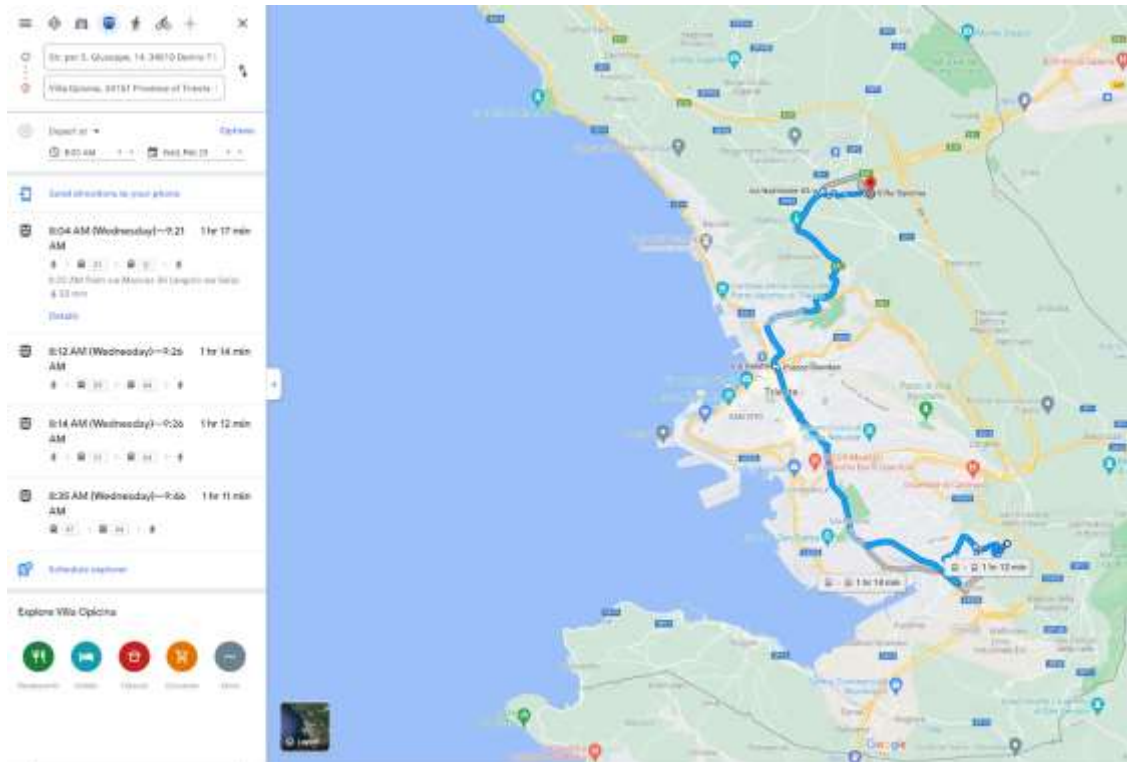
STREETLIGHT DATA
Big Data for Mobility



IMPORTANT TERMINOLOGIES

❖ Mode Imbalance

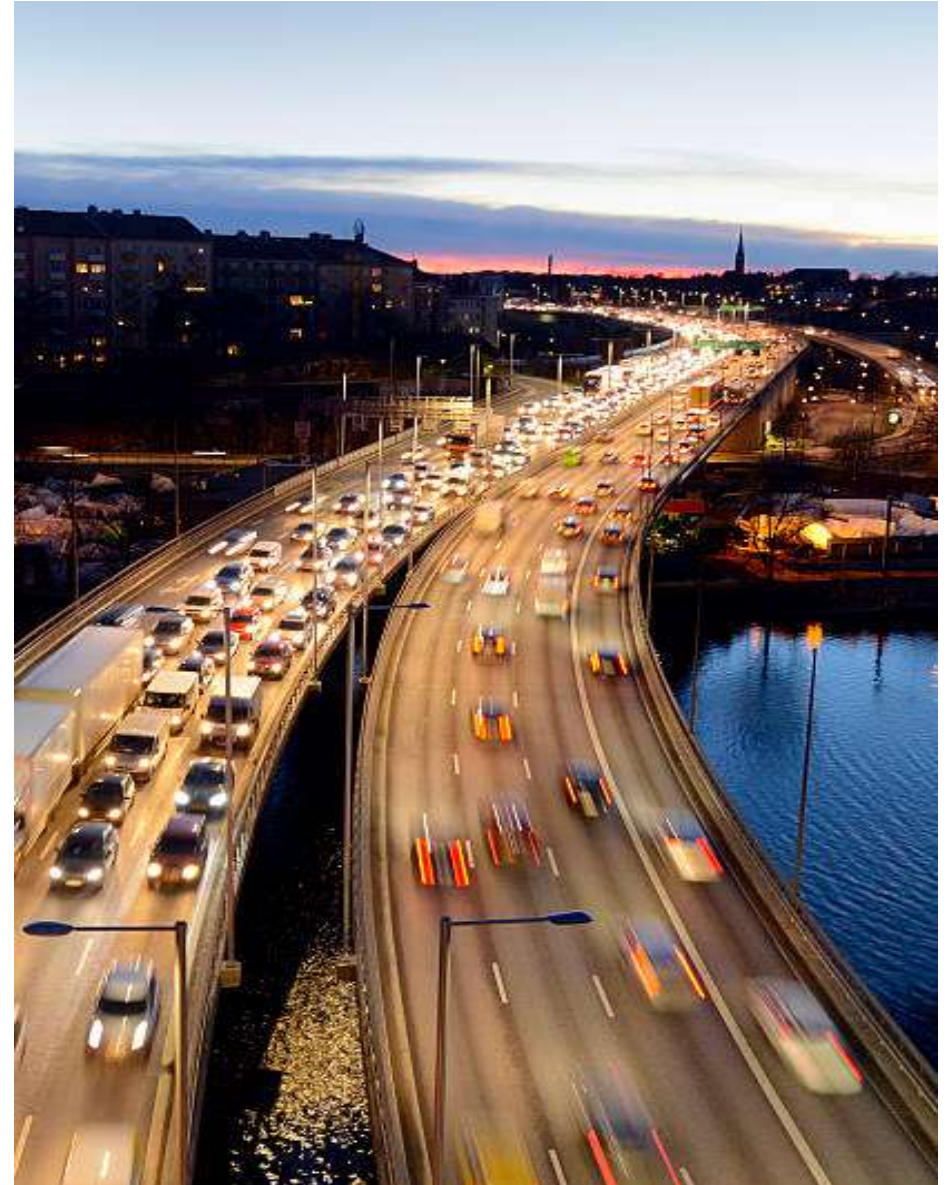
- The difference in travel time when using two different modes of transport (for example car vs. public transit).



PROBLEM CAUSED BY MODE IMBALANCE

Those who can afford a car will be more likely to buy and use one. This leads to problems with:

- ❖ Sustainability
- ❖ Urban sprawl
- ❖ Higher segregation
- ❖ Traffic congestion
- ❖ Parking demand, ...



PROBLEM CAUSED BY MODE IMBALANCE

Those who cannot afford a car will be limited in their choice of:

- ❖ Home location
- ❖ Jobs/hobbies
- ❖ Interpersonal relationships



DIAGNOSING MODE IMBALANCE



Mode Imbalance

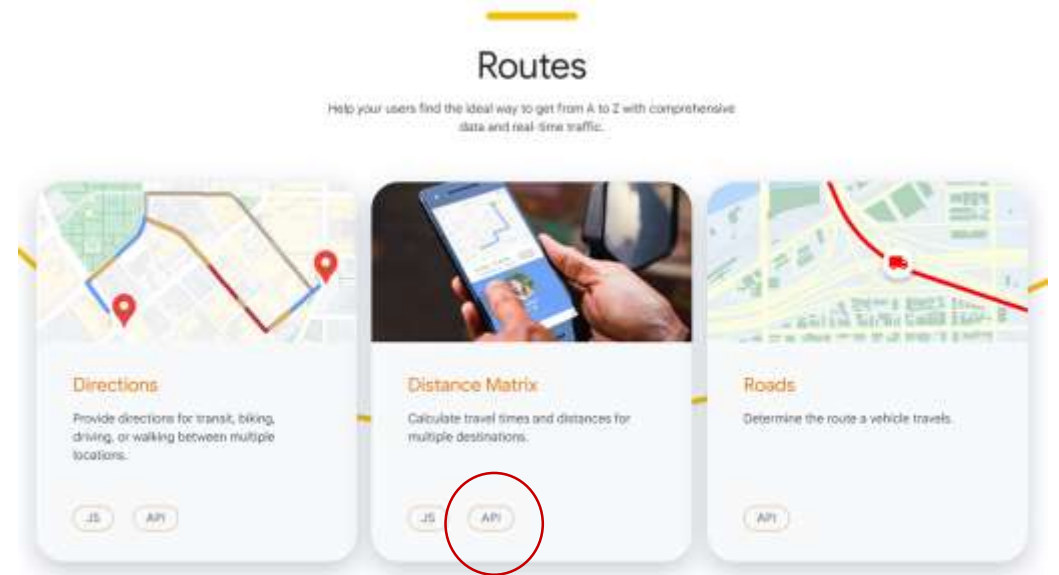
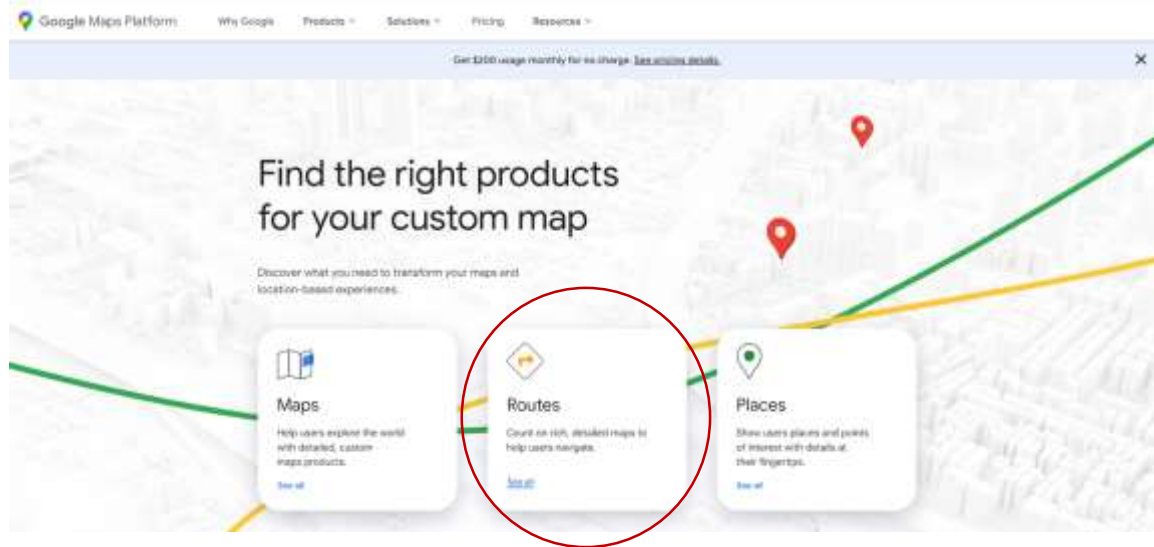
Steps to Get OD Matrices and Analyze Mode Imbalance

Overview

- ❖ How to get Google API key
- ❖ How to get OD matrices for transit and drive from Google Distance Matrix API
- ❖ How to create matrices
- ❖ Analyze asymmetry matrices and mode imbalance
- ❖ Compare travel time with demand data
- ❖ Use graph convolutional neural networks to understand how the travel mode imbalance for a given a trip is influenced by other nearby trips.

Getting Google API Key

<https://mapsplatform.google.com/maps-products/>



After Finishing with Payment Info Page

The screenshot shows the Google Cloud Platform console interface. At the top, there is a navigation bar with the Google Cloud Platform logo, the project name "My First Project", and a search bar. The main content area displays a "Welcome, Sadegh" message and a "Get started" section with various product cards like "Try Compute Engine", "Try Cloud SQL", and "Begin with". A modal dialog box is overlaid on the screen, titled "Google Cloud Platform" and "Welcome Sadegh!". The dialog contains a message about a \$300 free trial and a series of four questions to help tailor the user experience. The first question, "What best describes your organization or needs?", is selected and has a dropdown menu with "Please select*" as the current option. A "NEXT" button is visible below the dropdown. The dialog also has "CLOSE" and "DONE" buttons at the bottom right.

Google Cloud Platform

My First Project

Search Products, resources, docs (/)

Home

View all products

PINNED

- IAM & Admin
- Billing
- APIs & Services
- Marketplace
- Compute Engine
- Cloud Storage
- VPC network
- Kubernetes Engine
- BigQuery
- SQL
- Security
- Cloud Run
- Google Maps Platform

MORE PRODUCTS

Welcome, Sadegh

Get started with Google Cloud

Get started

Try Compute Engine
4 minutes
Learn how to create a VM instance in Google Cloud Engine.
• Custom machine types with memory and vCPU options
• Preemptible VM instances for lower costs
• Right-sizing options to optimize resource utilization
Monthly estimated cost: \$0.00
[START TUTORIAL](#)

Try Cloud SQL
10 minutes
Learn how to get started with a fully managed relational database service for MySQL, PostgreSQL, and SQL Server.
• Fully managed database set up in minutes
• Easily migrate from existing databases
• Integrate with any application with full database compatibility
[START TUTORIAL](#)

Begin with

Get up and running quickly by checking off common tasks

[GO TO CHECKLIST](#)

Setting up Google Cloud for scalable, production-ready enterprise workloads? Use the [Google Cloud setup checklist](#) designed for administrators.

What's covered

- Reviewing billing, credits, and projects
- Finding products and APIs
- Adding resources to a project
- Understanding and calculating pricing

Google Cloud Platform

Welcome Sadegh!

Your free trial includes \$300 in credit to spend over the next 90 days. To help us serve you better, please answer 4 questions.

- What best describes your organization or needs?
- What brought you to Google Cloud?
- What are you interested in doing with Google Cloud?
- What best describes your role?

[NEXT](#)

[CLOSE](#) [DONE](#)

Creating a Project and API Key

Free trial status: \$300.00 credit and 91 days remaining - with a full account, you'll get unlimited access to all of Google Cloud Platform.

DISMISS ACTIVATE

LEARN Home

Google Cloud Platform Trieste

Search Products, resources, docs (/)

Google Maps Platform Credentials Distance Matrix API + CREATE CREDENTIALS DISABLE

Overview
APIs
Metrics
Quotas
Credentials
Support
Solution Library NEW
Map Management
Map Styles

Credentials compatible with

To view all credentials visit [Credentials in API](#)

Remember to configure the OAuth

API Keys

Name	Creation date	Restrictions ↑	Key	Actions
No API keys to display				

API key
Identifies your project using a simple API key to check quota and access

OAuth client ID
Requests user consent so your app can access the user's data

Service account
Enables server-to-server, app-level authentication using robot accounts

Help me choose
Asks a few questions to help you decide which type of credential to use

CONFIGURE CONSENT SCREEN

Recommended for you

Maps Console Quick Tour
An overview of the different pages of the Maps Console.
Tutorials

Restrict your API key
Learn how to prevent unauthorized usage of your API key by restricting it.
Tutorials 3 min

Maps Customization
Learn how to use the new Maps customization features.
Tutorials 5 min

You might also like

Tutorials
Walkthroughs and guides

Resources
Pricing, release notes, and tools

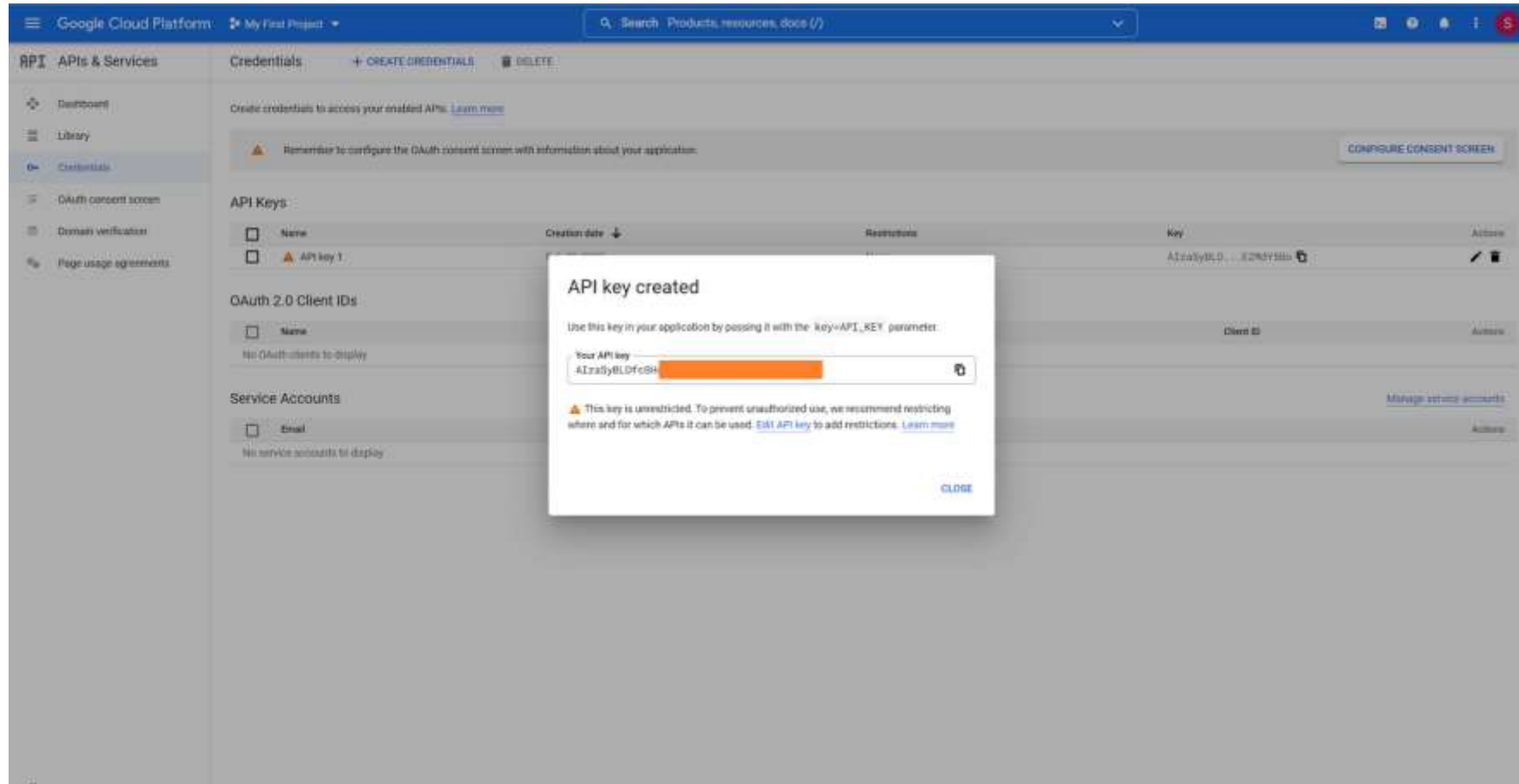
API & references
API and command-line resources

Support
Product support topics

All product documentation

Not seeing what you need? Give feedback

Copying and Storing the API Key



Distance Matrix API

**Important Points to Know When Using Distance
Matrix API**

OVERVIEW OF HOW TO WORK WITH DISTANCE MATRIX API

<https://developers.google.com/maps/documentation/distance-matrix/overview>

The screenshot shows the Google Maps Platform documentation page for the Distance Matrix API. The page is titled "Overview" and is part of the "Web Services > Distance Matrix API" section. The navigation bar includes "Overview", "Products", "Pricing", "Documentation", "Blog", and "Community". A search bar and language selector (English) are also present. The main content area is divided into three columns: a left sidebar with a table of contents, a central main content area, and a right sidebar with a "On this page" table of contents.

Distance Matrix API

- Overview
- Get Started
- Setup
 - Set up in Cloud Console
 - Using API Keys
- Best Practices
 - Web Service Best Practices
 - Client Libraries
- Billing and Monitoring
 - Usage and Billing
 - Reporting and Monitoring
- Policies and Terms
 - Policies
 - Terms of Service
- Other Web Service APIs
 - Directions API
 - Routes Preferred API
 - Elevation API
 - Geocoding API
 - Geolocation API
 - Places API
 - Roads API
 - Time Zone API

Overview

This service is also available as part of the client-side [Maps JavaScript API](#) or for server-side use with the [Java Client](#), [Python Client](#), [Go Client](#) and [Node.js Client](#) for Google Maps Services.

Introduction

The Distance Matrix API is a service that provides travel distance and time for a matrix of origins and destinations. The API returns information based on the recommended route between start and end points, as calculated by the Google Maps API, and consists of rows containing `duration` and `distance` values for each pair.

Note: This service does not return detailed route information. Route information can be obtained by passing the desired single origin and destination to the [Directions API](#).

Before you begin

This document is intended for developers who wish to compute travel distance and time between a number of points within maps provided by one of the Google Maps APIs. It provides an introduction to using the API and reference material on the available parameters.

Before you start developing with the Distance Matrix API, review the [authentication requirements](#) (you need an API key) and the [API usage and billing](#) information (you need to enable billing on your project).

On this page

- Introduction
- Before you begin
- Distance Matrix requests
- Request parameters
- Required parameters
 - destinations
 - origins
- Optional parameters
 - arrival_time
 - avoid
 - departure_time
 - language
 - mode
 - region
 - traffic_model
 - transit_mode
 - transit_routing_preference
 - units
- Distance Matrix examples
- Traffic information
- Location Modifiers
- Distance Matrix responses
 - DistanceMatrixResponse
 - DistanceMatrixStatus
 - DistanceMatrixRow
 - DistanceMatrixElement
 - Fare
 - DistanceMatrixElementStatus
 - TextValueObject

FORMAT OF REQUESTING DATA

<https://developers.google.com/maps/documentation/distance-matrix/overview>

Distance Matrix examples

The following example uses latitude/longitude coordinates to specify the destination coordinates:

```
URL  cURL  JavaScript  Python  Java  Ruby  Go  Postman

import requests

url = "https://maps.googleapis.com/maps/api/distancematrix/json?origins=40.6655101%2C-73.8918896999

payload={}
headers = {}

response = requests.request("GET", url, headers=headers, data=payload)

print(response.text)
```

★ **Note:** Snippets generated from [OpenAPI specification](#) on [GitHub](#).

FORMAT OF REQUESTING DATA

<https://developers.google.com/maps/documentation/distance-matrix/overview>

```
import requests
```

```
url = "https://maps.googleapis.com/maps/api/distancematrix/json?origins=40.6655101%2C-73.89188969999998  
&destinations=40.659569%2C-73.933783%7C40.729029%2C-73.851524%7C40.6860072%2C-  
73.6334271%7C40.598566%2C-73.7527626&key=YOUR_API_KEY"
```

```
payload={}  
headers = {}
```

```
response = requests.request("GET", url, headers=headers, data=payload)
```

```
print(response.text)
```

%2C means , (comma)
%7C means | (pipe character)

Learn more about URL Encoding:
https://www.w3schools.com/tags/ref_urlencode.asp

IMPORTANT CONSTRAINTS

1. Length of URL (see this [link](#))

Note: URLs must be [properly encoded](#) to be valid and are limited to 8192 characters for all web services. Be aware of this limit when constructing your URLs. Note that different browsers, proxies, and servers may have different URL character limits as well.

2. Time (same link)

Time should be in “Unix epoch” (or “seconds since epoch”), not human-readable date.

3. Number of Elements Per Request (see this [link](#))

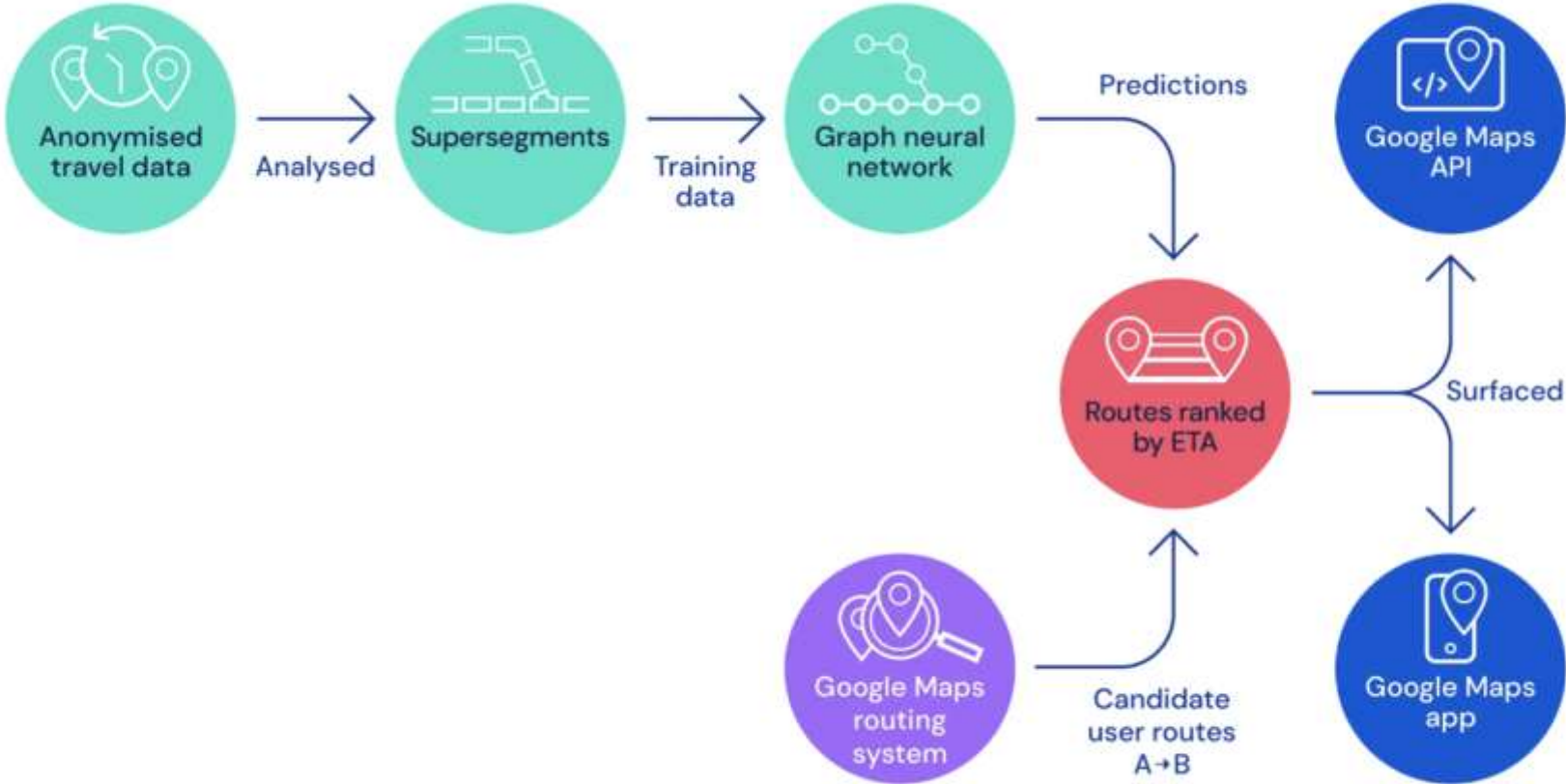
Maximum 100 elements per server-/client-side request

Maximum of 25 origins or 25 destinations per request

Graph neural networks

—

Estimated time of arrival prediction (Deepmind)



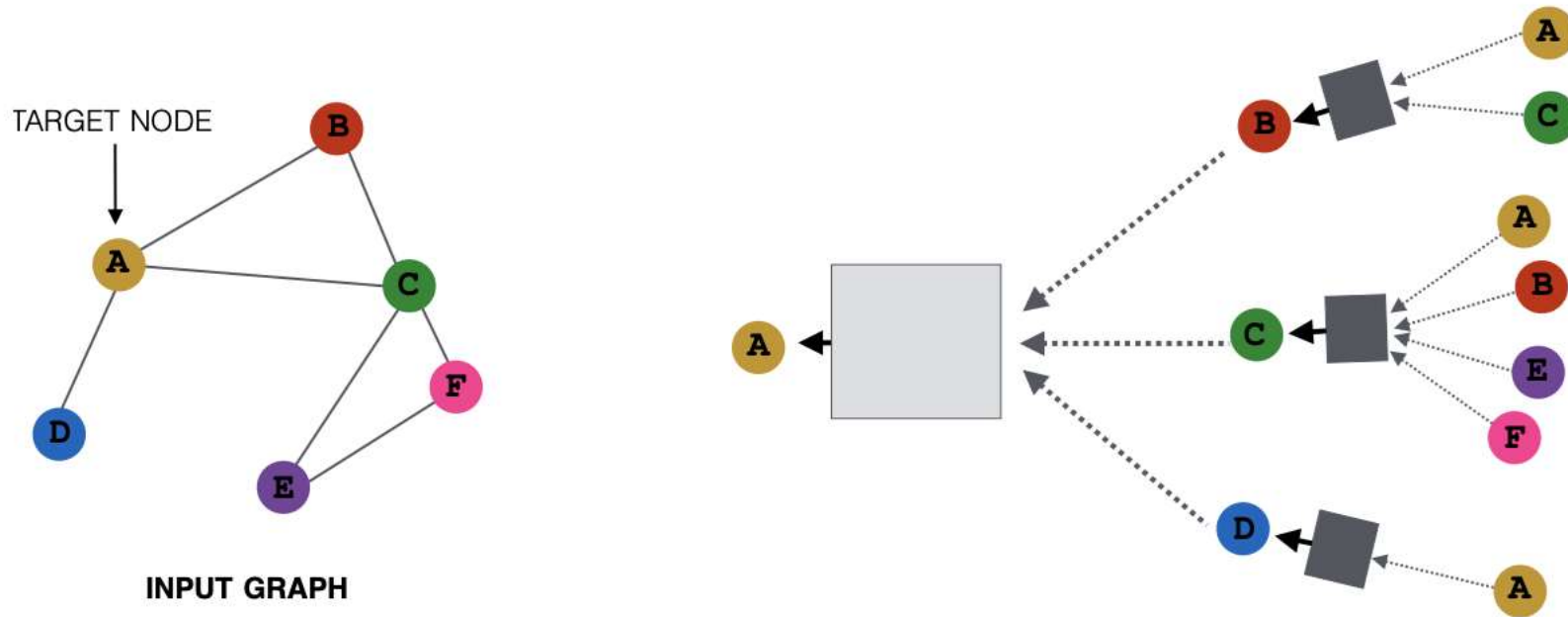
The model architecture for determining optimal routes and their travel time.

Estimated time of arrival prediction

<https://deepmind.com/blog/article/traffic-prediction-with-advanced-graph-neural-networks>

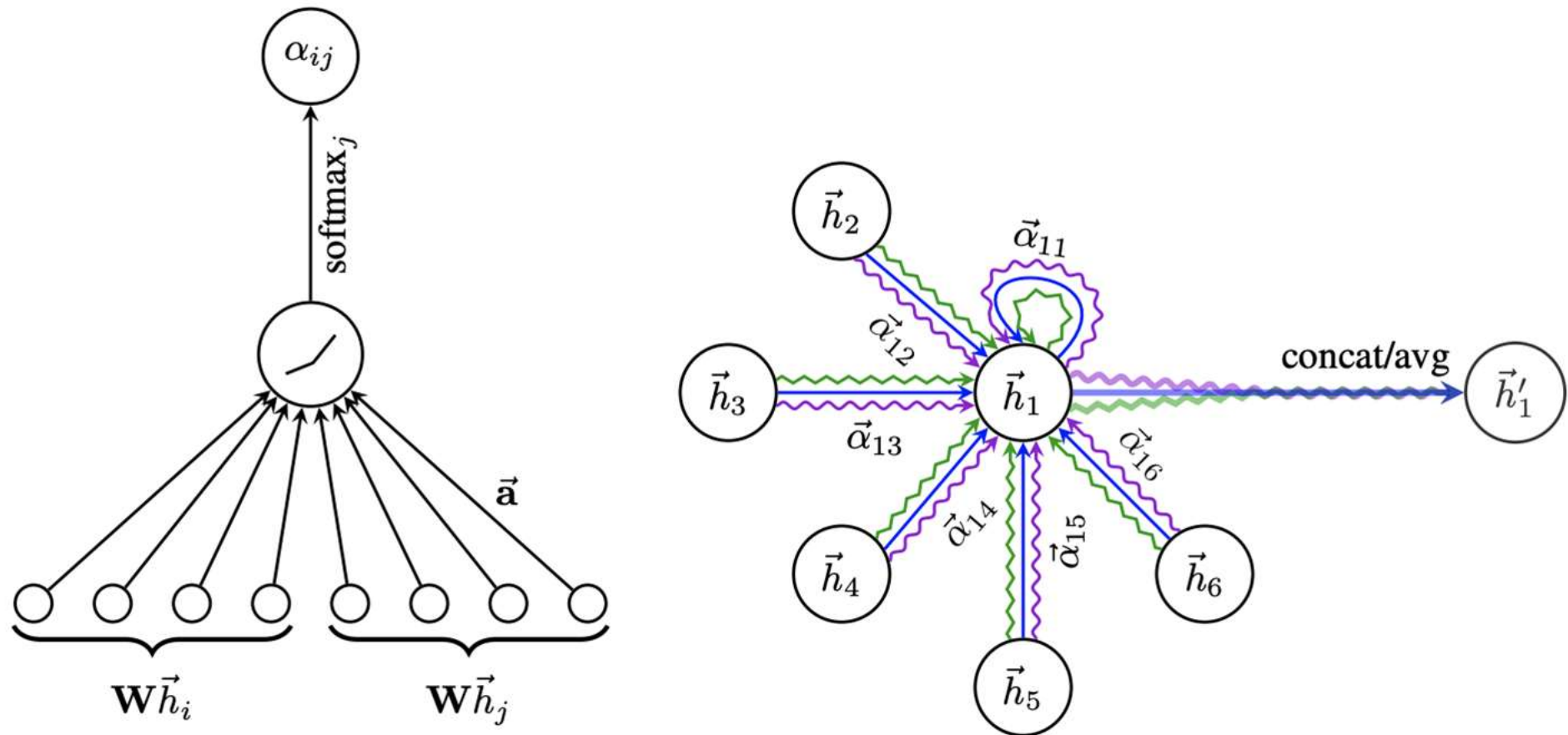
GNNs: The basics

<https://snap-stanford.github.io/cs224w-notes/machine-learning-with-networks/graph-neural-networks>



Graph attention networks

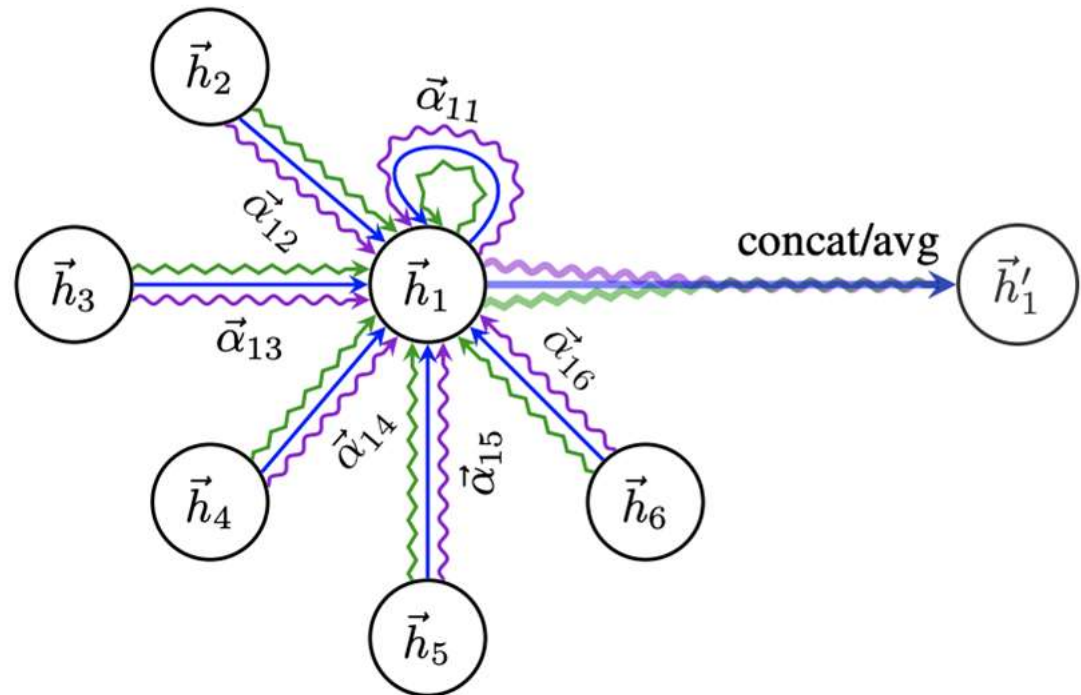
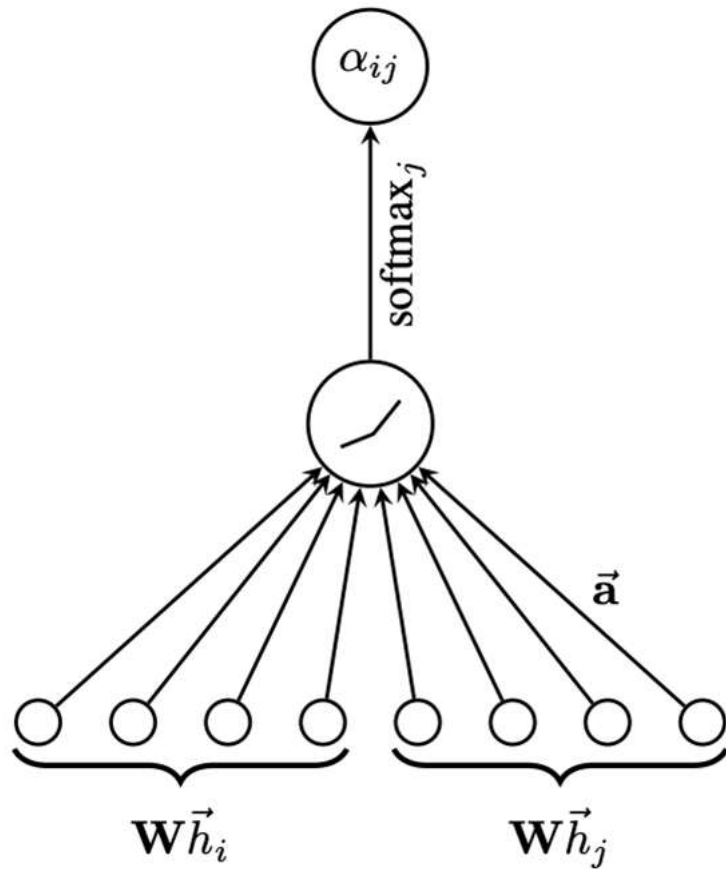
<https://arxiv.org/pdf/1710.10903.pdf>



Graph attention networks as diffusion

<https://arxiv.org/pdf/1710.10903.pdf>

$$\frac{\partial}{\partial t} \mathbf{x}(t) = (\mathbf{A}(\mathbf{x}(t)) - \mathbf{I})\mathbf{x}(t) = \bar{\mathbf{A}}(\mathbf{x}(t))\mathbf{x}(t)$$



Estimating key links without demand data

<https://arxiv.org/pdf/1710.10903.pdf>

$$\frac{\partial}{\partial t} \mathbf{x}(t) = (\mathbf{A}(\mathbf{x}(t)) - \mathbf{I})\mathbf{x}(t) = \bar{\mathbf{A}}(\mathbf{x}(t))\mathbf{x}(t)$$

