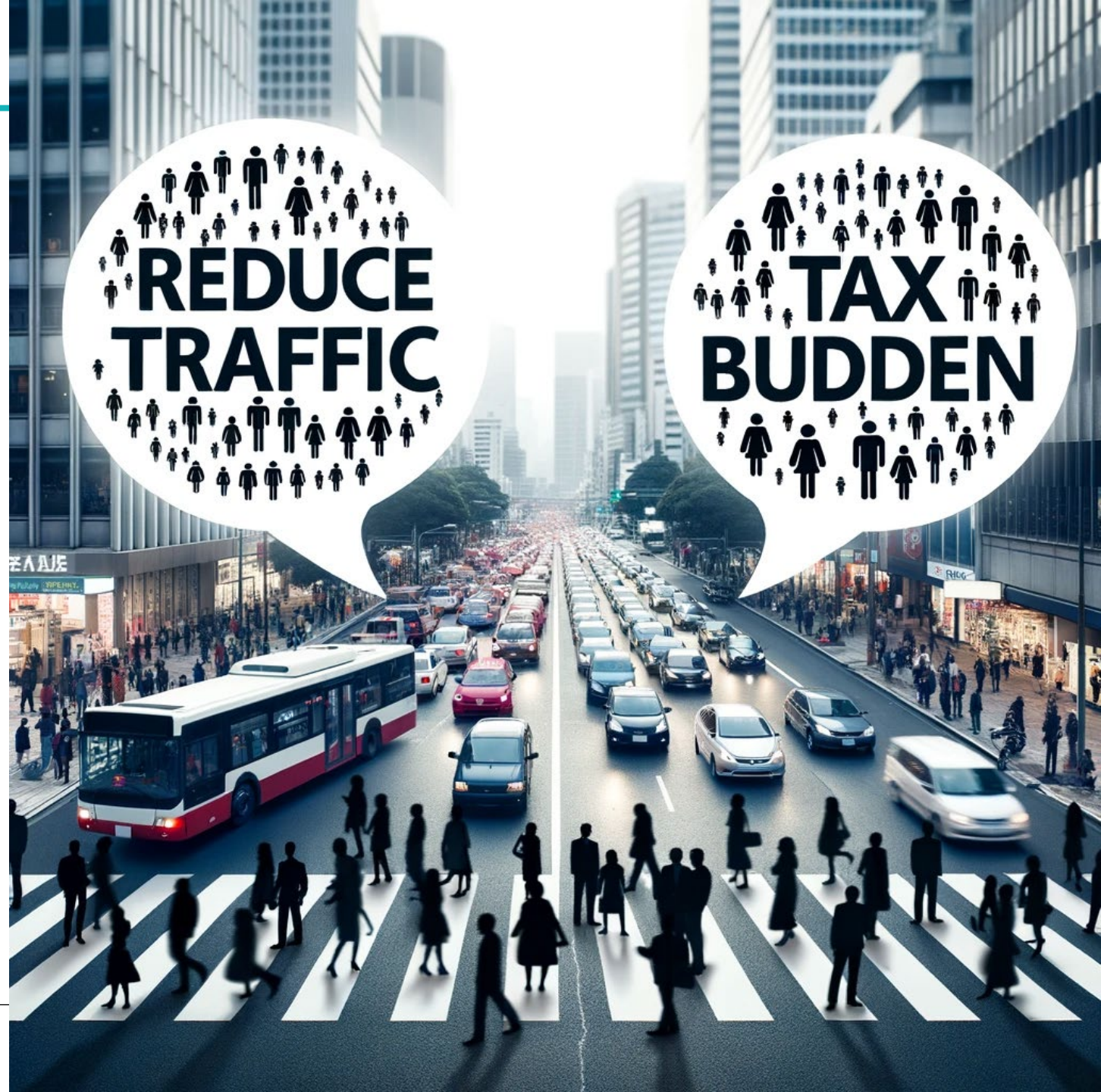

The voices behind congestion pricing: unveiling the social backgrounds of supporters and opponents through a large language model

Yang Yang, Yan Song
Department of City and Regional Planning,
UNC-Chapel Hill



NYC Congestion Pricing Plan



- A plan has been debated for decades, finally approved in 2019, but its implementation was delayed multiple times
- Aims to reduce traffic and air pollution
- Charge \$9~\$23 on Drivers Entering Midtown and Lower Manhattan
- The money from congestion pricing will be used for NYC Metropolitan Transit Agency Operation

Debate on Congestion Pricing

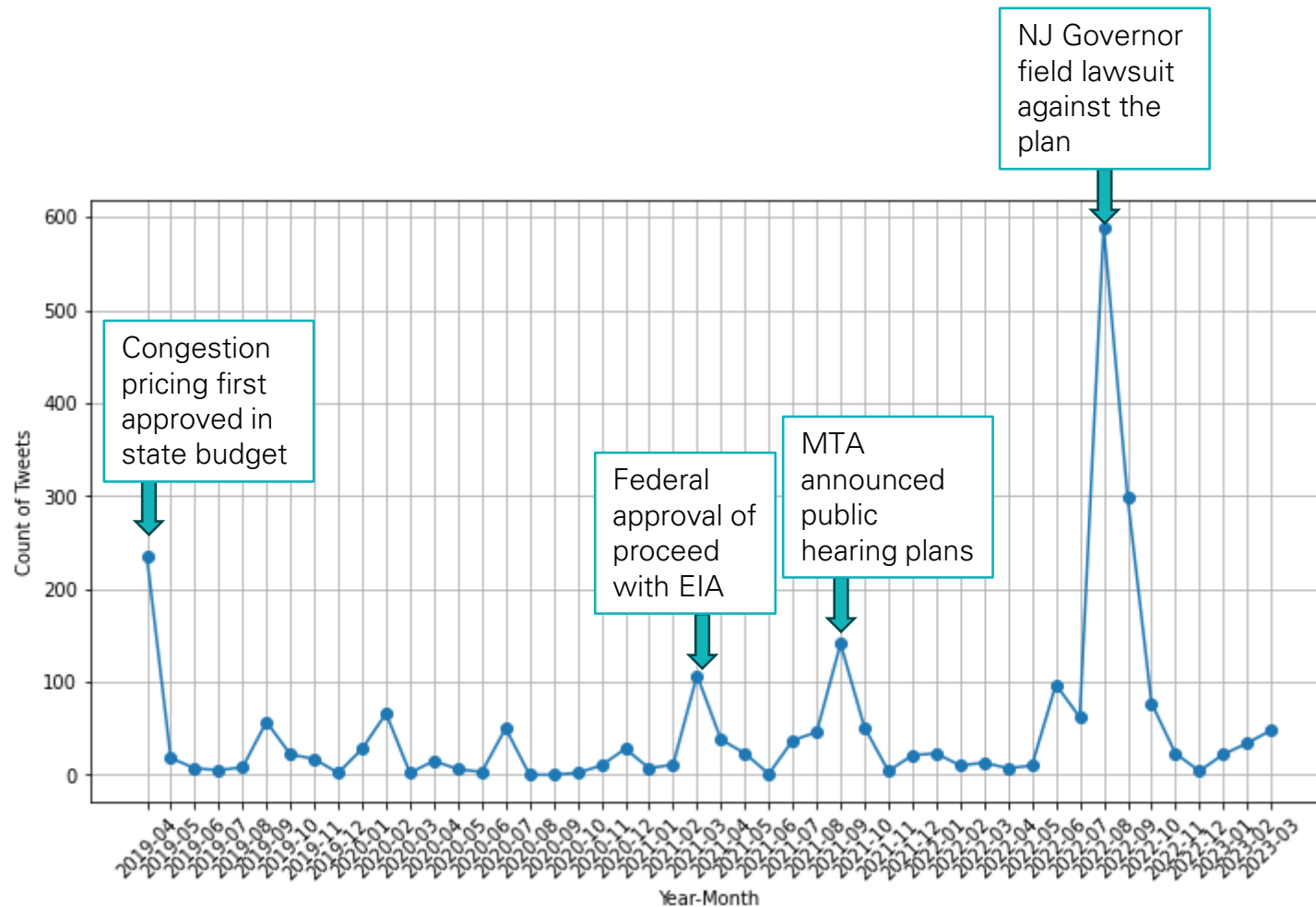
Supporters

- **Operation**
 - Reducing Traffic Congestion
- **Environment Benefits**
 - Air pollution
 - Noise
 - Safety
- **Equity**
 - Revenue Generation for Public Transit
 - Subsidization for non-driver

Opponents

- **Operation**
 - Effectiveness in Reducing Congestion
 - **Economic**
 - Negative Impact on Local Businesses
 - **Equity**
 - Economic Burden for Commuters
 - Fairness of Exemptions
 - Vulnerable groups living farther away are disproportionately affected
-

Continuous Debate on Social Media



We collected 2,386 tweets since NYC congestion pricing has been approved. It includes 1,710 original tweets from 1,416 distinct accounts.

When there was a milestone, there was discussion on Twitter. Social media data can assist planners to quickly respond to hot public topics.

We manually labeled 100 tweets for validation, and also used other third party validation datasets.

Analyzing social media data with machine learning is not a new thing

- Sentiment Analysis and Keyword Extraction on Twitter Data with classic natural language processing models (NLP) are Abundant (Chakraborty & Sharma, 2019; Grant-Muller et al., 2015; Park et al., 2022)
- Why is it not widely applied in practices?

Model Limitation

Accuracy not high enough

Task Specific

Data Reliability

Noise

Representation of population

Capability

Misinterpret sarcasm and irony

Context Understanding

Cost

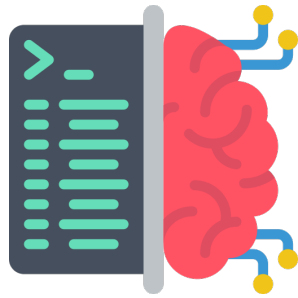
Machine Learning Knowledge

Linguistic Knowledge

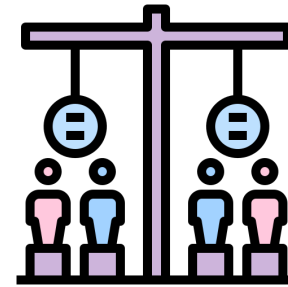
Large Language Model May Help on Those Issues

- **Generative Pre-trained Transformer Model** (GPT-4)
 - **Generative:** Not limited to specific task, Natural Language Prompt and Answer
 - **Pre-trained:** Already have learnt many linguistic and social science knowledge
 - **Transformer:** A new language model that evaluate documents based on entire context
-

The Goal of Our Study



Model Performance Comparison

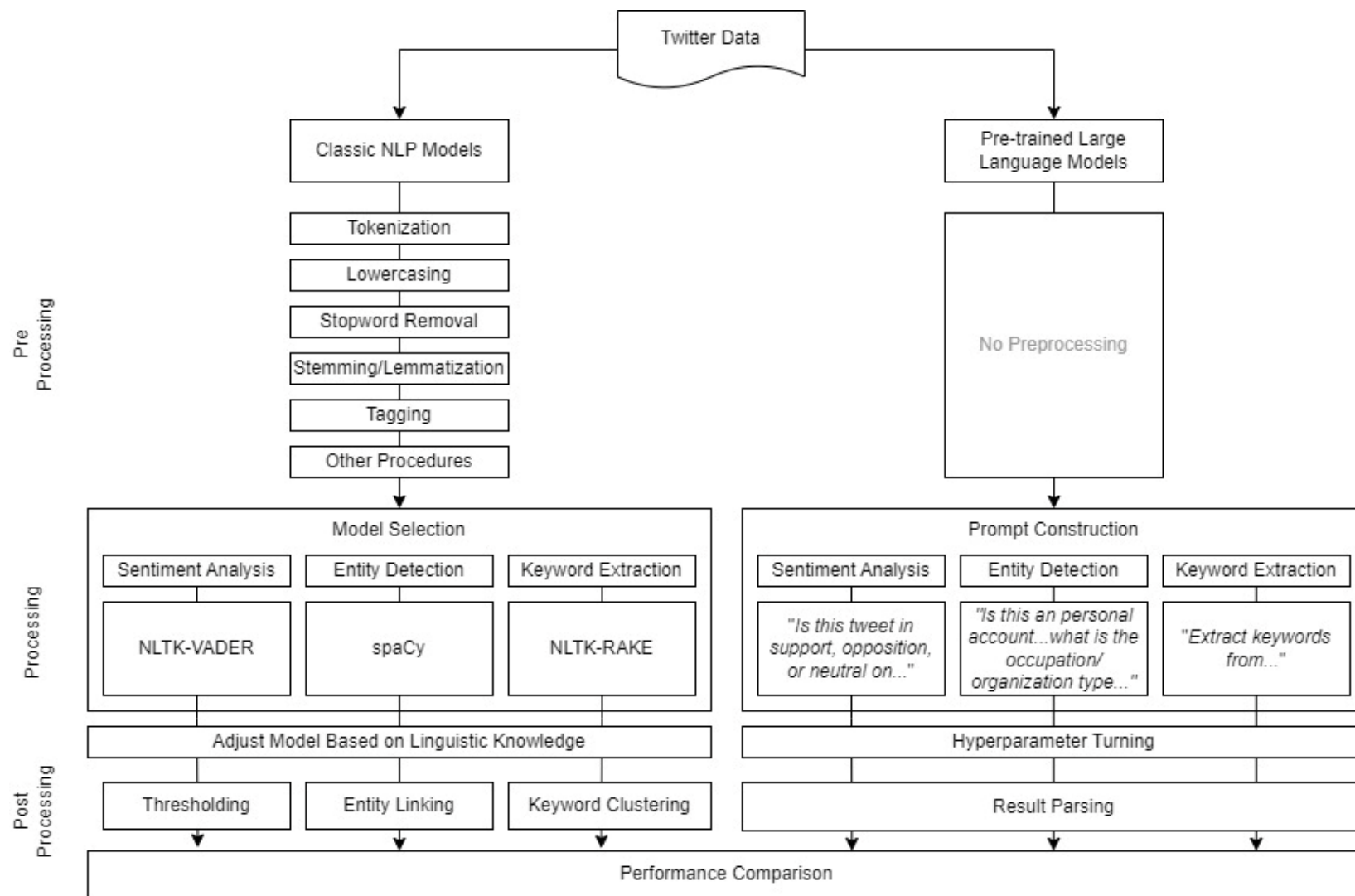


Social Equity Discussion

Use classic models and GPT-4 model to do:

1. Sentiment Analysis
 2. Account Type, Social Economic Status Speculation (Occupation Type for Individual, and Entity Type for Organization)
 3. Keyword extraction and Topic Modeling
-

Comparison of classic model and large language model workflow



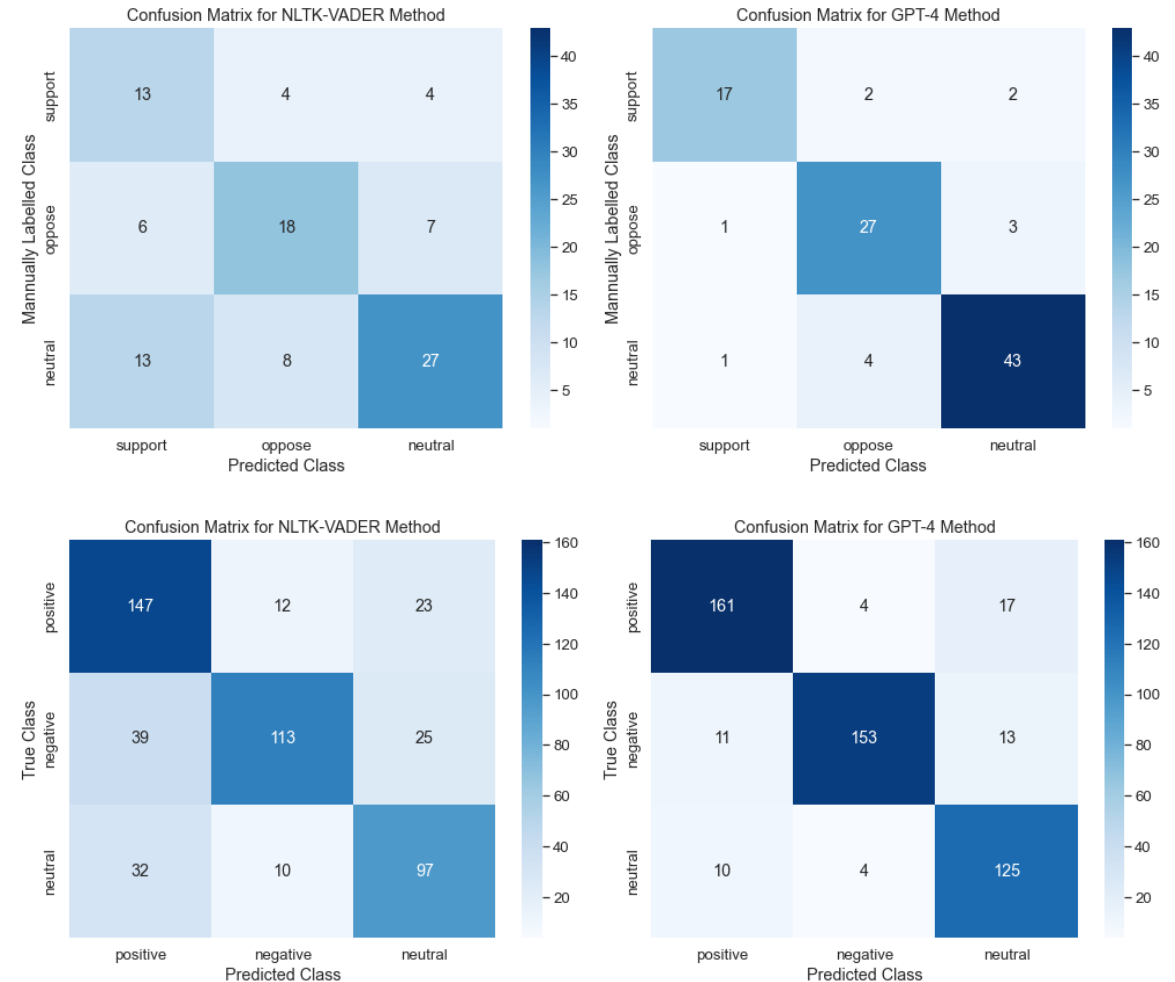
More Accurate!

- Validated two models on internal dataset (manually labelled, n=100) and third-party dataset
- GPT-4 outperform classic models on sentiment analysis and SES speculation

Accuracy Comparison

Task	Classic Model	GPT-4
Sentiment Analysis - Internal Dataset (n=100)	58%	87%
Sentiment Analysis - 3rd Party Dataset (n=498)	71%	88%
Account Type Speculation - Internal Dataset (n=100)	64%	92%
Individual Occupation Speculation - Internal Dataset (n=100)	N/A	81%
Organization Type Speculation - Internal Dataset (n=100)	N/A	94%
Keyword Extraction (IoU > 50%) - Internal Dataset (n=100)	80%	75%
Keyword Extraction (IoU > 50%) - 3rd Party Dataset (n=2000)	80%	85%

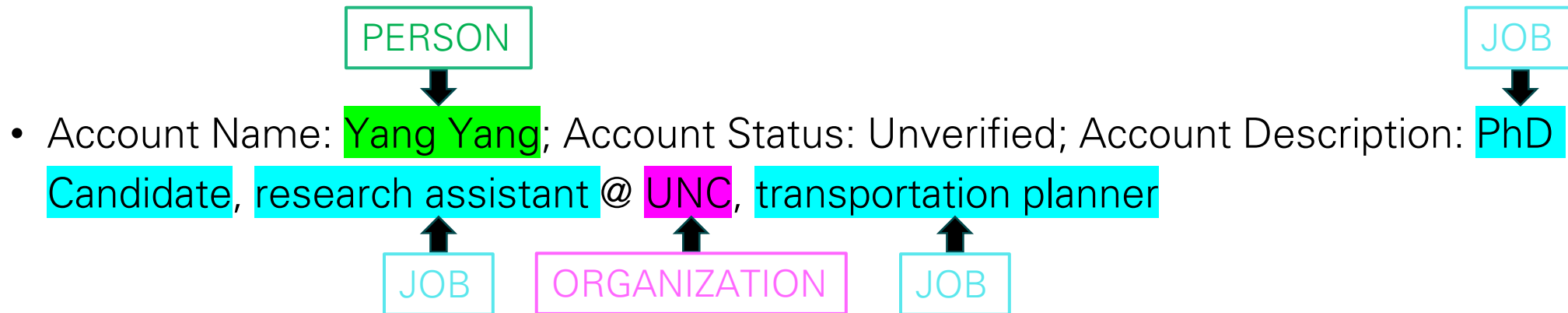
Confusion matrix for sentiment analysis



Speculate Deeper Information

- Account Name: Yang Yang; Account Status: Unverified; Account Description: PhD Candidate, research assistant @ UNC, transportation planner

How the classic entity recognition model understands this...



Speculate Deeper Information

- Account Name: Yang Yang; Account Status: Unverified; Account Description: PhD Candidate, research assistant @ UNC, transportation planner

How GPT-4 model understand this...



Based on the provided information, the Twitter account with the name "Yang Yang" appears to be a personal account.



Yes, the owner of the Twitter account "Yang Yang" does introduce their job among the provided information. Their job as mentioned in the account description is "transportation planner."

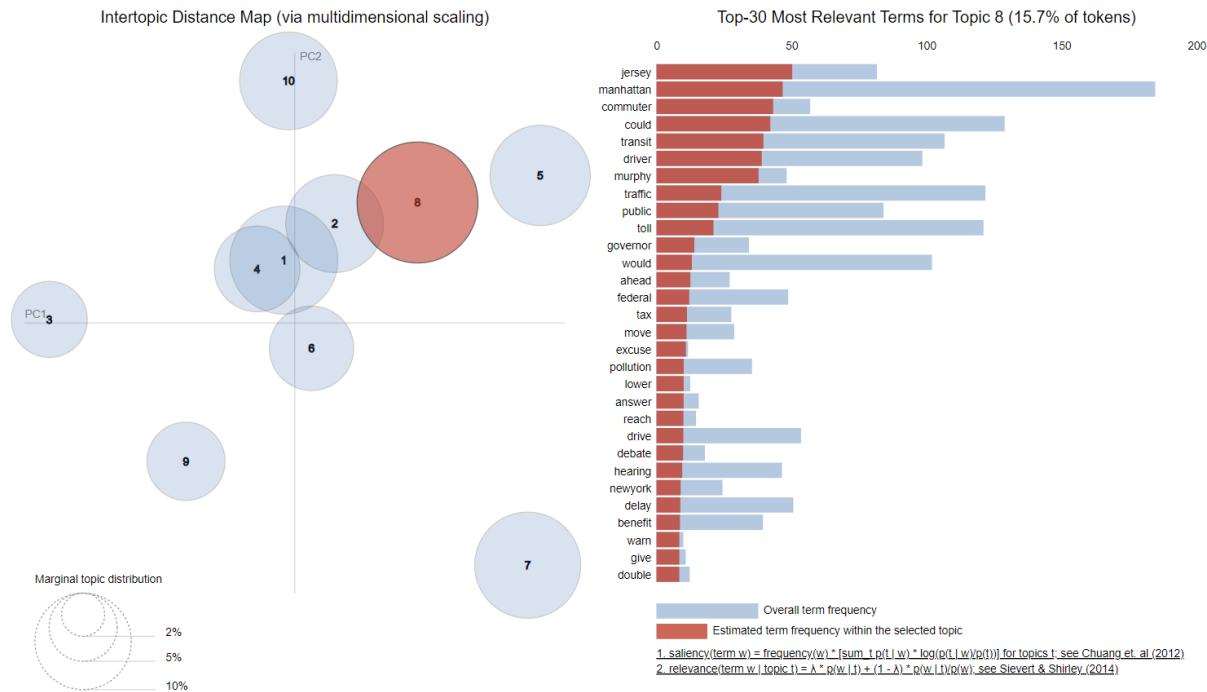


The job of "transportation planner" typically falls under the "Urban and Regional Planners" category in the U.S. Standard Occupational Classification (SOC) System 2018. This category is part of the "Life, Physical, and Social Science Occupations" major group, which is one of the highest-level classifications in the SOC system.

Also more interpretable...

Classic Model:

Keyword Extraction → Topic Modeling



GPT Model:

Ask for Keywords and Main Arguments in Bullet Point Format

Support for NYC Congestion Pricing:

- Seen as necessary for reducing congestion and improving public transit.
- Provides revenue for public transportation improvements.
- Encourages public transportation use and reduces cars on the road.

Opposition to NYC Congestion Pricing:

- Viewed as regressive and a burden on working-class individuals.
- Critics doubt its effectiveness in reducing congestion and emissions.
- Concerns about its impact on lower-income residents and the taxi industry.

Political Disagreements:

- Politicians have differing stances, with some opposing and others supporting it.
- NJ Governor Phil Murphy's opposition and call for an environmental impact study are noted.

Environmental and Health Considerations:

- Seen as crucial for reducing air pollution and improving public health.

Impact on Yellow Cabs and Taxi Industry:

- Concern that it may reduce demand for yellow cabs and harm the taxi industry.

Desire for Infrastructure Improvements:

- Calls for using congestion pricing revenue for infrastructure projects.

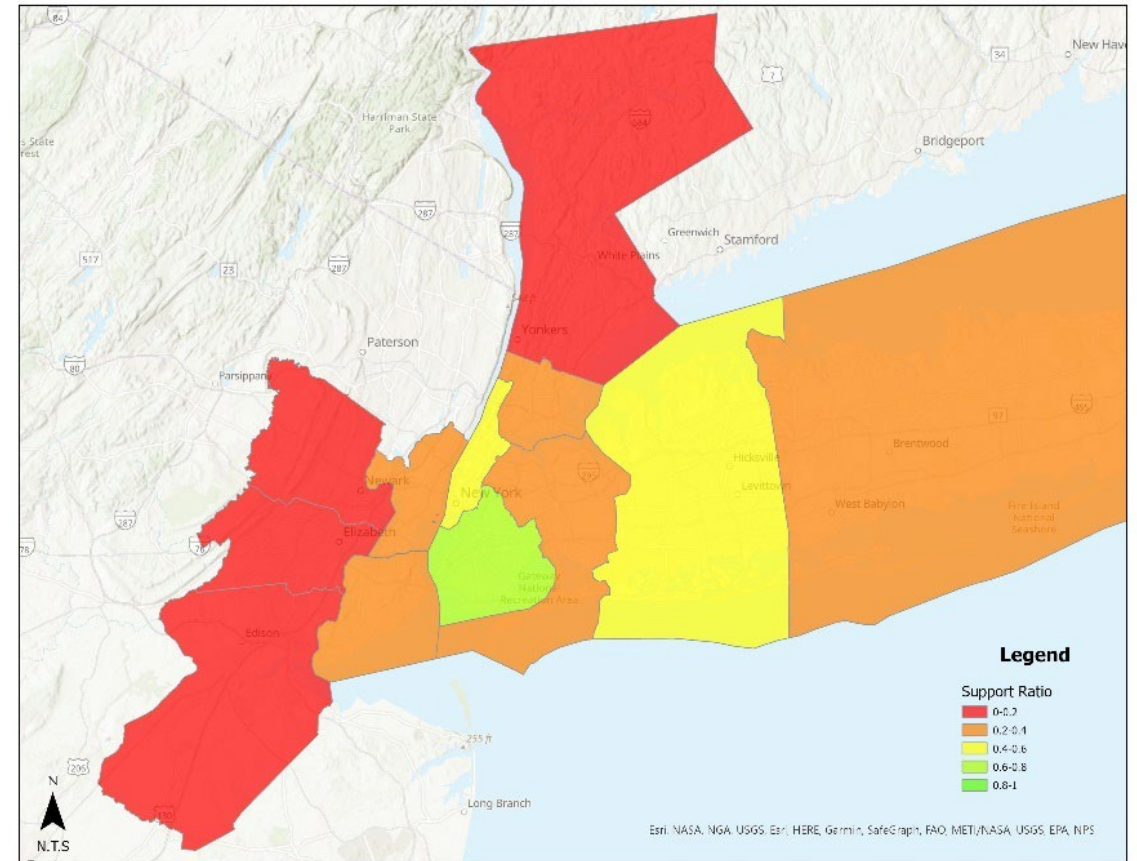
Critique of Media Coverage:

- Criticisms of media for perceived bias and lack of meaningful comparisons in coverage.

Spatial Distribution of Opinion Groups

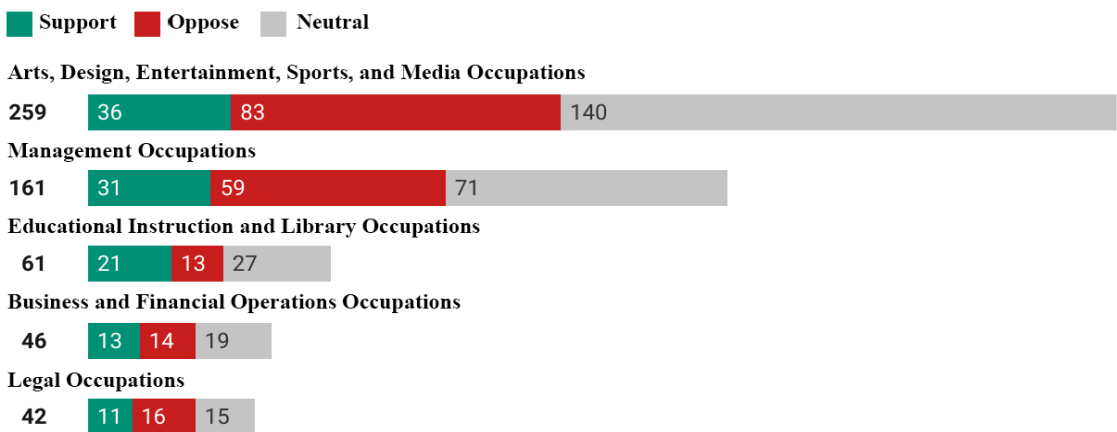
- The plan is more favored by residents living in central boroughs
- Those with longer commuting distances are more likely to oppose congestion pricing

Support Ratio in Counties with More Than 5 Individuals Tweet about Congestion Pricing

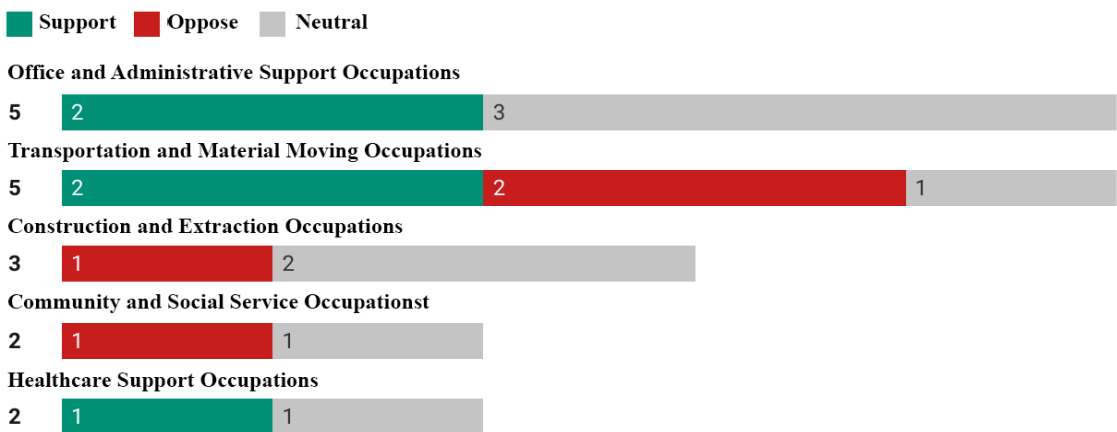


Sentiment Analysis by Occupation Groups

Top Five Occupation Groups



Bottom Five Occupation Groups



White-collar and gold-collar jobs are over represented in the dataset, blue-collar populations are marginalized

Individuals in media, management, and legal occupations tend to be more opposite to the plan
Educational and library science occupations and computer science occupations are significantly supportive

May due to the travel demand of the occupations and office locations

Keywords and Main Arguments

Educational Instruction and Library Occupations

61

21

13

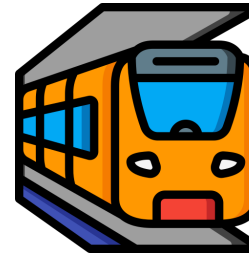
27

- Keywords: Congestion Pricing, NYC (New York City), Pollution, MTA, Manhattan, Traffic, Public Transportation, Environmental, Economic, Bronx

Main Arguments: Support for Congestion Pricing:



Environmental
Benefits



Revenue for Transit



Traffic Management

Criticism and Concerns about Congestion Pricing:



Shift of Pollution



Burden for Local
Business



Slow Implementation



Exemptions

Sentiment Analysis by Organization Types

Media accounts tend to be neutral

Government accounts shows significant opposition

- More than two thirds of the 28 tweets were posted by NJ Chamber of Commerce and Republican Conference of the NYS

	Number of Tweets Posted				Chi-Square
	Support	Oppose	Neutral	Total	
Organizational Accounts	162 (15%)	212 (20%)	679 (64%)	1053	
Media	106 (16%)	113 (17%)	460 (68%)	679	0.001*
Nonprofit	43 (24%)	56 (31%)	81 (45%)	180	0.000*
Enterprise	5 (4%)	19 (15%)	102 (81%)	126	0.000*
Government	1 (4%)	12 (43%)	15 (54%)	28	0.005*
Institution	2 (10%)	10 (50%)	8 (40%)	20	0.322
Others	5 (25%)	2 (10%)	13 (65%)	20	0.003*

Pros and Cons of LLM Application in Participatory Planning

Pros

- **Low Deployment Cost**
 - Basic programming knowledge
 - Minimal linguistic knowledge
- **Impressive Model Performance**
 - Higher accuracy rate
 - Handle complex tasks
- **Logically Interpretable**
- **Fast Response Speed**
 - Get result in days
 - Replicable workflow

Cons

- **Higher usage cost**
 - GPT-4 API is not Free (but it is affordable)
- **Randomness of result**
 - 0.1 % chance may give a non-standard answer
- **Statistically Uninterpretable**
- **Data Acquisition Uncertainty**
- **Privacy Issue**
 - Is it ethical to analyze deeper information from social media?

Conclusions

- Analyzing social media data by large language model is a promising method for planners to use to supplement traditional public participation channels
 - Real-time, high-frequency, accurate public opinion review
 - Extend to a wide range of planning practices
 - Help to eliminate selection bias in social media data and promote vulnerable groups

Potential Planning Usages

Evaluate sentiment and opinion

Analyze spatial and socioeconomic background of opinion groups

Understand and Trending Public Concerns

Find Key Influencers in Communities

Relationship between Tweeters

Etc...

Thanks for your questions!

If you have any questions about:

Data collection

Model tuning

Prompt engineering

Result validation

Etc.

please email me at yangyang@unc.edu

Backup Slides

Data Collection

Twitter Dataset

- Search keywords “New York City congestion pricing” or “NYC congestion pricing” from April 1, 2019, to April 1, 2023 on Twitter API v2
- 2386 Tweets from 1,416 distinct accounts
- 1710 Original Tweets or Retweets with Comments, 676 Pure Retweets
- 188 verified accounts, 1228 unverified accounts
- We manually labeled 100 tweets as internal validation dataset

Third Part Validation Dataset

- Sentiment 140 Dataset (498 Tweets with labelled emotion)
 - InsPec dataset (2000 abstracts with labelled keywords)
-

Prompts finally used

For sentiment analysis task:

- *"Is this tweet in support, opposition, or neutral on the NYC congestion plan: "tweet content"? Reply with support, oppose, or neutral without explanation."*

For profile SES speculation task:

- *This is the Twitter account name "account id", and it is an "account verification status" account. Account description is "account description". Is this a personal account or an organizational account? Answer this question with personal, organizational, or not sure without explanation.*
- *This is the Twitter account name "account id", and it is an "account verification status" account. Account description is "account description". Does the owner introduce his job among that information? reply job name only. reply \"not sure\" if it is hard to determine. no explanation.*
- *What is the class that job "jobname" belongs to in the U.S Standard Occupational Classification System 2018? Use the highest level classification with 23 categories in this system. Answer only the full name of the classification. No explanation.*
- *This is the Twitter account name "account id", and it is an "account verification status" account. Account description is "account description". What is the type of this organization? Reply with one from Government, Institution, Enterprise, Non-profit, Media, Others, or not sure. No explanation.*

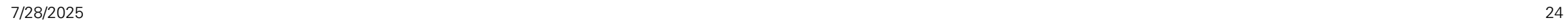
For keyword extraction task:

- *Extract keywords from this tweet: \"{tweet}\". Only reply with the keywords, no explanation.*

Label Name	Standardized Answer Key
Opinion	Support, Oppose, Neutral
Owner Type	Personal, Organizational, Not Sure
Occupation	According to Occupation Classification of the US Bureau of Labor Statistics, Not Sure
Organization Type	Government, Institution, Enterprise, Media, Non-Profit, Others, Not Sure
Keyword	No Standardized Answer Key

SES Result

Account Types	Number of Tweets Posted				
	Support	Oppose	Neutral	Total	Chi-Square
Personal Accounts	213 (18%)	388 (33%)	585 (49%)	1186	
Not Sure About Owner Occupation	73 (14%)	185 (35%)	265 (51%)	523	
Arts, Design, Entertainment, Sports, and Media Occupations	36 (14%)	83 (32%)	140 (54%)	259	0.101
Management Occupations	31 (19%)	59 (37%)	71 (44%)	161	0.353
Educational Instruction and Library Occupations	21 (34%)	13 (21%)	27 (44%)	61	0.002*
Business and Financial Operations Occupations	13 (28%)	14 (30%)	19 (41%)	46	0.171
Legal Occupations	11 (26%)	16 (38%)	15 (36%)	42	0.160
Computer and Mathematical Occupations	11 (55%)	4 (20%)	5 (25%)	20	0.000*
Architecture and Engineering Occupations	6 (35%)	1 (6%)	10 (59%)	17	0.030*
Life, Physical, and Social Science Occupations	4 (27%)	1 (7%)	10 (67%)	15	0.094*
Healthcare Practitioners and Technical Occupations	2 (14%)	6 (43%)	6 (43%)	14	0.715
Sales and Related Occupations	0 (0%)	1 (17%)	5 (83%)	6	0.226
Military Specific Occupations	2 (40%)	2 (40%)	1 (20%)	5	0.314
Office and Administrative Support Occupations	0 (0%)	1 (20%)	4 (80%)	5	0.349
Transportation and Material Moving Occupations	2 (40%)	0 (0%)	3 (60%)	5	0.210
Construction and Extraction Occupations	0 (0%)	1 (33%)	2 (67%)	3	0.696
Community and Social Service Occupations	0 (0%)	1 (50%)	1 (50%)	2	0.762
Healthcare Support Occupations	1 (50%)	0 (0%)	1 (50%)	2	0.406
Organizational Accounts	162 (15%)	212 (20%)	679 (64%)	1053	
Media	106 (16%)	113 (17%)	460 (68%)	679	0.001*
Non-profit	43 (24%)	56 (31%)	81 (45%)	180	0.000*
Enterprise	5 (4%)	19 (15%)	102 (81%)	126	0.000*
Government	1 (4%)	12 (43%)	15 (54%)	28	0.005*
Institution	5 (25%)	2 (10%)	13 (65%)	20	0.322
Others	2 (10%)	10 (50%)	8 (40%)	20	0.003*
Not Sure About Ownership	21 (14%)	49 (33%)	77 (52%)	147	
Grand Total	396 (17%)	649 (27%)	1341 (56%)	2386	



Keywords and Main Arguments

Educational Instruction and Library Occupations



- **Keywords: Congestion Pricing, NYC (New York City), Pollution, MTA, Manhattan, Traffic, Public Transportation, Environmental, Economic, Bronx**

Main Arguments:

Support for Congestion Pricing:

Environmental Benefits: Advocates believe congestion pricing will reduce traffic and pollution, making NYC greener.

Economic Benefits: The funds from the pricing will be reinvested in public transportation improvements.

Traffic Management: Supporters argue that reduced congestion will improve travel times and enhance public transit experience.

Criticism and Concerns about Congestion Pricing:

Shift of Pollution: There are concerns that the measure will move pollution from Manhattan to other areas, notably the Bronx.

Economic Impact: Some believe it might hurt businesses and that these costs will be passed onto consumers.

Implementation Delays: The slow pace of approval and prolonged review process have caused frustrations.

Exemptions: Questions arise over who gets exemptions, potentially undermining the system's effectiveness.

Keywords and Main Arguments

Computer and Mathematical Occupations

20

11

4

5

- **Keywords: Congestion Pricing, NYC, Transit, Pollution, Tolls, Public, Money, Traffic New Jersey, Implementation**

Main Arguments:

Support for Congestion Pricing:

It could raise funds for increased public transit investment.
Aims to reduce vehicle traffic and thereby combat pollution.

Criticism and Concerns about Congestion Pricing:

Seen by some as a money grab without genuine intent.
Concerns about the high proposed tolls, potentially reaching \$23.
Opposition from New Jersey due to perceived high tolls.
Calls for quicker implementation by city and state officials.

Key takeaways from the social equity lens

- The speaking power of vulnerable populations are also marginalized on social media platform, we need to rebalance the results when running social media data analysis
 - Social economic background and home locations have significant impact on the viewpoints towards congestion pricing
 - Besides running social media analysis, city agencies should also use the platform as a channel to promote their policy
-

Keywords and Main Arguments

Computer and Mathematical Occupations

20

11

4

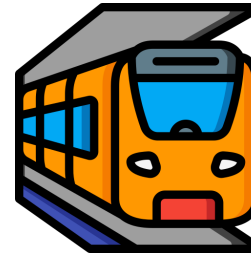
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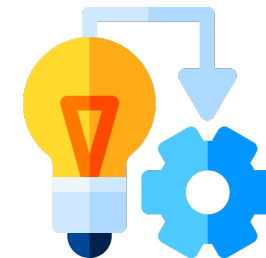
Criticism and Concerns about Congestion Pricing:



Toll Too High



Burden for New
Jersey Commuters



Slow Implementation
