The Estimation of Congestion Cost and Congestion Price in Bangkok, Thailand

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Abstract

Traffic congestion is a global issue that costs billions of dollars in economic loss, multiple hours a day, and thousands of lives due to pollution. This research delves into the negative externalities to the society that traffic congestion has imposed. Bangkok, Thailand was ranked the world's most congested city in 2017 by INRIX. Drawing upon economic theory, this study explores the congestion cost and congestion price as an effective mechanism to address these externalities and reduce the associated deadweight loss. Congestion Pricing is a strategy employed to tackle traffic congestion and enhance the effectiveness of road utilization by charging fluctuating tolls for accessing specific roads or designated areas during peak hours when traffic is most congested. It has proven to be effective in various global cities, including Singapore, London, and Stockholm. In the United States, New York City is the most recent city that is considering congestion pricing. Research on congestion cost and congestion price have been conducted worldwide including Bangladesh, Chile, China, India, and Thailand. This research uses a comprehensive equation derived from previous research to estimate congestion costs, including Travel Time Cost, Deadweight Loss, Externality Consumption, Vehicle Operation Cost, and Road Traffic Accident Costs. The findings of this research reveal that the congestion cost in Bangkok, Thailand is approximately $15.4 billion. In comparison with previous studies and cities facing similar congestion challenges, it is suggested that an effective congestion pricing mechanism for Thailand should be set above $2.3. These findings contribute to a deeper understanding of the economic impact of traffic congestion in urban areas and emphasize the potential benefits of congestion pricing policies in alleviating the negative externalities.

Keywords: traffic congestion, congestion cost, congestion price, negative externality

I. Introduction

Traffic congestion is one of the most pressing issues across the world as cities continue to experience growth in population and vehicle ownership. In addition to the lost time, negative externalities such as gas, travel delays, and pollution contribute to the community due to traffic congestion. These externalities could decrease the quality of life across the world. Air pollution from traffic congestion in 83 U.S. cities contributed to more than 4.2 million premature deaths (World Health Organization) and over $18 billion in medical expenses annually (Harvard School of Public Health, 2011). This does not include wasted time and fuel costs which are estimated to be between $166 billion (Texas Transportation Institute, 2019) and $305 billion (INRIX Global Traffic, 2019). Given these numbers, traffic congestion is an important issue that requires attention.

Some of the most congested cities in the world are London, Chicago, Paris, Boston, and New York City. All of which have over 100 hours lost to traffic per person per year (Bloomberg, 2023). Bangkok was named the world's most congested traffic city (INRIX Global Traffic, 2017), the 9th deadliest road in the world, and 1st in Southeast Asia (World Health Organization, 2018). Traffic also accounts for 28% of greenhouse gas emissions in Thailand (Energy Policy and Planning Office (EPPO), 2017).

With these issues, many politicians and economists are trying to find the best solution to reduce traffic congestion. Congestion Pricing is a strategy employed in urban transportation to tackle traffic congestion and enhance the effectiveness of road utilization. The policy implementation is to charge fluctuating tolls for accessing specific roads or designated areas during peak hours when traffic is most congested. The ultimate objective of congestion pricing is to decrease traffic congestion, minimize air pollution, and reduce travel times while encouraging alternative transportation options like public transit, cycling, or walking. The revenues will also be used to improve the transportation system in the future. It also has the economic benefit that congestion pricing will offset the deadweight loss.

In this paper, I will present a literature review of congestion cost and pricing strategies around the world. Then, I will calculate the congestion cost of Bangkok, Thailand, using an equation from research by Chakraborty that includes traffic congestion cost, travel time cost, deadweight loss, externality cost, vehicle operating cost, and road traffic accident cost. Next, I will discuss the appropriate congestion pricing that will offset the deadweight loss, comparing the congestion cost of Bangkok, Thailand to other cities in the United States. Lastly, I will state conclusions.

Literature Review

Congestion pricing is an innovative and market-driven economic strategy aimed at mitigating traffic congestion in urban areas. This approach involves the implementation of dynamic fees or tolls on vehicles accessing certain high-traffic zones or using specific roadways during peak hours. The primary objective of congestion pricing is to reduce traffic congestion, improve overall transportation efficiency, and promote sustainable urban development. By creating financial incentives for drivers to adjust their travel behavior, such as opting for public transport, carpooling, or traveling during off-peak hours, congestion pricing seeks to optimize the utilization of limited road capacity.

A negative externality theory states that negative externalities occur when there is an overproduction or overconsumption of goods or services that impose spillover costs or effects on third parties who are not involved in the transaction and do not receive benefits from the effects.

Traffic congestion is undoubtedly a negative externality. As vehicles take up the space on the road, especially during peak hours, they slow down the traffic leading to wasted time, reduced productivity, fuel consumption, and other priceless variables such as time and energy. Moreover, the elevated emissions of greenhouse gasses and air pollutants from idling vehicles contribute to air pollution and climate change, further exacerbating environmental degradation. Additionally, traffic congestion can hinder the efficiency of public transportation systems and emergency services, leading to delays and compromised access to critical situations.

Different regions have adopted unique models of congestion pricing tailored to their urban environments. For instance, cities like London and Singapore have established cordon-based systems, where vehicles are charged upon entry into designated congestion zones. In contrast, Stockholm employs a time-of-day pricing scheme, varying charges based on traffic intensity. Some cities, such as Milan, have implemented area-based congestion pricing, targeting specific zones with higher pollution levels. While they have different strategies, the underlying principle remains consistent which is to use financial incentives to offset the cost that traffic causes.

Congestion Pricing Around the World

Congestion Pricing first started in Singapore in 1975. Singapore introduced the Electronic Road Pricing (ERP) system which charges vehicles for entering specific roads during peak hours. The system charges travelers using cameras and license plate reading equipment. Since then, Singapore has developed other systems and is the leading country in congestion pricing. Singapore was able to reduce 74,000 to 41,500 vehicles during the morning congested time, the average velocity peak increased by 30%, and public transportation usage increased from 33% to

69% (Ye, 2012). Reduced traffic by 13% and increased vehicle speed by 22 percent (US Department of Transportation, 2006).

Following Singapore's success, London implemented the system in 2003. London's strategy is to set a standard per-day charge for vehicles traveling within a zone around the inner ring road. The system functioned in a similar style to Singapore by recording vehicle registration numbers in the database and using cameras to capture the license plate. This strategy led to a 15% reduction in traffic, and congestion time dropped by 30% (Ye, 2012). Additionally, the majority of car users shifted to public transportation.

In early 2006, Stockholm had the testing period for congestion pricing which had a favorable result as public acceptance went from 30% approval pre-trial to 51.3% approval post-trial. Immediately after the implementation, Stockholm saw a 22% drop in vehicle trips, a decrease in travel times, and a large shift to public transportation. Traffic accidents involving injuries decreased by 5-10% and emissions decreased by 14% in the inner city (US Department of Transportation, 2006).

Congestion Pricing in the United States

With congestion pricing success, some roads and cities in the United States adopted congestion pricing as well. High Occupancy Toll lanes on I-15 in San Diego are one of the first roads that adopted congestion pricing. In 1998, single-occupant vehicles paid a per-trip fee every time they drove through the I-15 HOT lanes. The dynamic tolls change based on the level of traffic. This congestion pricing generated $2 million in annual revenue. (US Department of Transportation, 2006)

The other California road that adopted congestion pricing is SR 91 Express Lanes in Orange County. The price is adjusted based on the traffic every three months. During the non-peak hours, the tolls are reduced to half. The revenues went to pay for construction and operating costs. (US Department of Transportation, 2006)

Lee County, Florida offered an alternative congestion pricing strategy. In 1998, the city offered travelers a discount when they travel during specific off-peak periods. (US Department of Transportation, 2006)

New York City is the most recent U.S. city that has approved and will be implementing congestion pricing. The policy has been initiated since 2007 but wasn't fully executed due to several political reasons. In 2020, the congestion pricing law was approved by President Biden and is expected to be in effect by the end of 2023.

Congestion Cost

To calculate the congestion pricing, we must first know the congestion cost. In 2021, the congestion cost drivers in the top three most congested cities in the United States are $2,618 per year in Chicago, $2,270 in Boston, and $1,976 in New York City. When combining all drivers in each city, the congestion cost can be as high as $10.2 billion in New York City and $8.6 billion in Los Angeles (INRIX, 2019).

Many researchers have conducted congestion cost and price in countries similar to Thailand. This includes Bangladesh (Chakraborty, 2016, and Mohammad, Bhuiyan, and Sultana, 2013), Chile (Rizzi and De La Maza, 2017), Mexico (Parry and Timilsina, 2010), China (Ye, 2012) and India (Singh & Sarkar, 2009). One research studied Thailand (Ayaragarnchanakul and Creutzig, 2022). Each research has different specific vehicle groups, cost categories, and methodologies employed based on research interests and data availability. All studies include external costs of congestion, local air pollution, and accidents. Furthermore, most studies have extended their analysis to include factors such as noise pollution, global air pollution, and road damage.

Chakraborty (2016) used an equation that included several components that I found essential. This includes travel time cost, deadweight loss, externality cost, vehicle operating cost, environmental externality cost or air/noise pollution, and road traffic accident cost. This equation will be used to calculate the congestion cost for Bangkok, Thailand in this paper.

Mohammad, Bhuiyan, and Sultana (2013) found hidden causes of traffic congestion in Dhaka city and the overall consequences. They surveyed 400 people and analyzed data from the existing literature and Government of Bangladesh reports. They found several factors that cause traffic congestion in Dhaka city which impact socio-economic aspects. The study, however, did not measure the overall traffic congestion cost and its economic cost.

Singh & Sarkar, (2009) determined optimal congestion pricing in the central area of Delhi, Connaught Place, using two methods. The first method was analyzing the price where the external costs intersect with the revenue generated at different price levels. The second method was the price level needed to maintain a level of service. Using these methods, they found congestion prices for car and two-wheeler motorized vehicles.

Ayaragarnchanakul and Creutzig (2022) calculated the external costs of road transport in Bangkok by including air pollution, noise, climate change, traffic accidents, and congestion, to suggest optimal road pricing of $2.3 - $2.7.

II. Empirical Analysis

Congestion Cost in Bangkok, Thailand

To calculate congestion pricing, it's necessary to calculate the congestion cost to find the right equilibrium price that would balance the price and the cost. The cost of congestion can be estimated using five components:

1) Travel Time Cost (TTC)

2) Deadweight Loss (avoidable social cost) (DWL)

3) Externality Consumption (travel delay externality cost) (EC)

4) Vehicle Operation Cost or excess fuel cost due to congestion (VOC)

5) Road Traffic Accident Cost (RTAC)

It can be written mathematically as:

$$TCC = TTC + DWL + EC + VOC + RTAC$$ (Chakraborty, 2016)

Some components can be calculated directly while other components require further mathematical calculations, especially those that do not have a direct price such as travel time cost. In economic terms, the time spent on traveling has an opportunity cost as this time can be used for alternative activities that generate more value for drivers. The most widely used approach to estimate the opportunity cost is Value of Time (VOT), the monetary value that a person is willing to pay for a unit travel time reduction. Oftentimes, this is calculated as the hourly wage of the person.

Once the cost is calculated, politicians and economists can estimate the appropriate price accordingly.

Estimation of Travel Time Cost (TTC)

TTC = t/km(t x TT x VOT) + TTV (Chakraborty, 2016).

Where,

TTC = Travel time cost per vehicle-person per day,

t = % Trips

TT = Travel Time

VOT = Value of Time (varying according to travel condition, travel time, mode choice, travel purpose, etc.)

TTV = Travel Time Variability.

To adjust this model to best suit the data available, we will use TTC = TT x VOT.

Table 1: Calculation of Travel Time Cost

Travel Time Cost components	Value
Average time spent traveling	2 hours/day
Days working in a month	22 days
Minimum Wage per hour	$1.38 per hour
Total Travel Cost per person	$60.72 a month per person
Number of cars in Bangkok	11,304,846 cars
TTC for Bangkok vehicle owners	$686,430,249.12

Travel Time (TT)

The average time people spend on the road to commute from places is 2 hours a day, 22 days a month (Urban Creature, 2022). Therefore, Travel Time is 44 hours a month per capita.

Value of Time (VOT)

The minimum wage in Thailand is $11 (354 baht) a day which means that the minimum wage per hour is $1.38 (44.25 baht).

Total Travel Cost (TTC)

Multiplying Travel Time and Value of Time, the Total Travel Cost per person is $60.72 a month. As of 2022, Bangkok has 11 million registered cars. Therefore, the Total Travel Cost is $60.72 x 11,304,846 cars = $686,430,249 per month.

Estimation of Deadweight Loss (DWL)

Deadweight Loss is a cost to society created by market inefficiency, which occurs when supply and demand are out of equilibrium. Deadweight Loss can be applied to any deficiency caused by inefficient allocation of resources. (Investopedia, 2023). Bangladesh Road Transport Corporation (2007) estimated that Deadweight Loss is 30-55% of the TTC cost (Chakraborty, 2016) because the opportunity cost from traffic is estimated to be 30-55%. Individuals can be more efficient with their time and resources by 30-55% if traffic congestion is solved.

Therefore, DWL is 50% x $686,430,249 = $343,215,124.56 per month.

Estimation of External Cost as a result of traffic congestion (EC)

The external costs of road traffic derived from congestion, air and noise pollution, accidents, and global warming equal to ~$13.8 - $22.8 billion annually or 7% - 10.8% of GRP in 2017. The breakdowns are $1.1 - $4.3 billion for air pollution, $0.2 - $1.8 billion for climate change, $0.9 - $1.3 billion for noise, $9.7 billion for congestion, and $1.9 - $5.7 billion for accidents (Ayaragarnchanakul and Creutzig, 2022). Ayaragarnchanakul and Creutzig used several methods to calculate these numbers.

Table 2: Calculation of External Cost

External Cost	Costs
Air Pollution	$1.1 - $4.3 billion
Climate Change	$0.2 - $1.8 billion
Noise	$0.9 - $1.3 billion
Congestion*	$9.7 billion
Accidents*	$1.9 - $5.7 billion
Total External Cost	$13.8 - $22.8 billion
Total External Cost, excluding RTAC and Congestion Cost	$2.2 - $7.4 billion

Air Pollution

Ayaragarnchanakul and Creutzig used two approaches to calculate air pollution cost. The first approach is pollutant inventory. The inventory consists of five major air pollutants from the transport sector (CE Delft et al., 2011) including Particulate matter (PM2.5 and PM10), Nitrogen oxides (NOx), Non-methane volatile organic compounds (NMVOCs), and Sulfur dioxide (SO2). Each pollutant's unit cost factors or shadow prices depend on the magnitude of damage, covering health costs, building and material damages, and crop losses. The second approach focuses on the damage to health costs and the value of statistical life (VSL) for deaths involving air pollution such as cardiac, and respiratory (Ayaragarnchanakul and Creutzig, 2022).

Climate Change

Using two approaches, Ayaragarnchanakul and Creutzig first calculated total vkm, a weighted average of CO2-eq. by modes of transport and avoidance cost of climate change based on a cost-effectiveness analysis of achieving a policy target. Second, they used locally available data on the CO2 emission released from Thailand's transport sector and the contribution from the

BMR. Lastly, they also made assumptions about a constant amount of air pollutants and GHG emissions released for every kilometer traveled. (Ayaragarnchanakul and Creutzig, 2022).

Noise

Ayaragarnchanakul and Creutzig, 2022 extrapolate noise cost factors containing costs of annoyance and health (medical and premature death) due to traffic noise. Different levels of noise call for different cost factors. They also assumed that 50% − 75% of the citizens suffer from noise pollution.

Later in this paper, I will calculate Accidents and Congestion costs using the Chakraborty model, Road Traffic Accident Cost, and Congestion cost consecutively. Therefore, these two variables will be omitted from the equation from External Cost.

Thus, the total External Cost, excluding RTAC and Congestion Cost is $2.2B - $7.4B. The External Cost is an average to be $4.8 billion.

<u>Estimation of Vehicle Operating Cost (VOC)</u>

Vehicle Operating Cost can be calculated by considering the cost of vehicles, insurance, property taxes, fuel and gas, maintenance, and other essential services such as parking and express fees.

Table 3: Calculation of Vehicle Operating Cost

Vehicle Operating Cost components	Values
Number of cars	11,304,846
Vehicle Operating Cost	$281
Total VOC across Bangkok	$3,176,661,726

It's estimated that the monthly vehicle operating cost per car is $281 (฿9,000) (Sanook, 2021). Sanook surveyed people in Bangkok about the monthly cost they pay for vehicles. Everyone had different numbers due to car models and lifestyles. However, the average number of each category is $156 (5,000 baht) for gas, $47 (1,500 baht) for tolls, $50 (1,600 baht) for legislation and tax, $19 (600 baht) for auto repairs, and $9 (300 baht) for cleaning (Sanook, 2021).

Therefore, the total VOC is 11,304,846 cars * $281 = $3,176,661,726 per month.

Estimation of Road Traffic Accident Cost (RTAC)

Road Traffic Accident Cost (RTAC) goes beyond the vehicle damages and medical bills, it also includes motor-vehicle injuries that cause wage and productivity losses, medical expenses, administrative expenses, motor-vehicle damage, and employers' uninsured costs. This is called the economic cost. In addition to the economic cost, there are also comprehensive costs that include a measure of the value of lost quality of life (NSC Injury Facts).

Table 4: Total number of local road accidents in Thailand in May 2023 (Statista)

Type of Accidents	Numbers of Accidents	Economic Cost	Comprehensive Cost	Total Cost Per Accident	Total Cost in Thailand
Minor Injuries	64,140	$24,000	$120,000	$144,000	$9.236B
Senior injuries	20,550	$24,000	$120,000	$144,000	$2.959B
Moderate injuries	15,740	$40,000	$221,000	$261,000	$4.108B
Disability	2,290	$155,000	$1,016,000	$1,171,000	$2.681B
Death	250	$1,778,000	$12,474,000	$14,252,000	$3.563B

RTAC of Thailand	102,970				$22.548B
RTAC of Bangkok					$6.14B

Source: Statista and NSC Injury Facts.

Research from Statista shows five types of accidents: minor injuries, senior injuries, moderate injuries, disability, and death. There are 64,140 minor injuries in Thailand and the total cost per accident is $144,000, 20,550 senior injuries and the total cost per accident is $144,000, 15,740 moderate injuries and the total cost per accident is $261,000, 2,290 disabilities and the total cost per accident is $1,171,000, and 250 deaths and the total cost per accident is $14,252,000 (Statista, 2023).

Multiplying the number of accidents for each category with its corresponding total cost per accident, and then adding five types of accidents together, I found that the Total RTAC cost for Thailand is $22,548,090,000 per month. However, this number calculates the cost for the entire Thailand. Bangkok has 11.3 million cars, while Thailand as a whole has 42.5 million cars (Spring News, 2022). Bangkok captures 27.23% of total cars in Thailand.

Therefore, the RTAC cost for Bangkok is 27.23% * $22.548B is $6,139,538,634.89.

Total Traffic Congestion Cost

Table 5: Calculation of Traffic Congestion Cost

Traffic Congestion Cost components	Cost
Travel time cost (TTC)	$686,430,249.12

Deadweight loss (DWL)	$343,215,124.56
Externality cost (EC)	$4,800,000,000.00
Vehicle operating cost (VOC)	$3,176,661,726
Road Traffic Accident Cost (RTAC)	$6,139,538,634.89
Total Congestion Cost	$15,145,845,734.57

Through data and analysis, I found that the travel time cost (TTC) is $686,430,249, the deadweight loss (DWL) is $343,215,124, the externality cost (EC) is $4,800,000,000, the Vehicle operating cost (VOC) is $3,176,661,726, and Road Traffic Accident Cost (RTAC) is $6,139,538,634.

Therefore, the Total Congestion Cost is $15,145,845,734.57.

Table 6: Cost and Price of Congestion in U.S. cities vs. Bangkok

Cities	Cost of Congestion per city	Congestion Price
Chicago, IL	$9.5B	$0.55 - $8.00
Boston, MA	$4.3B	N/A
New York, NY	$10.2B	$9.00 - $23.00
Philadelphia, PA	$4.5B	N/A
Miami, FL	$4.5B	N/A
Los Angeles, CA	$8.6B	N/A but considering
San Francisco, CA	$2.6B	$2.17 - $6.50
Washington, D.C.	$3.5B	N/A but considering
Houston, TX	$3.7B	N/A

Atlanta, GA	$3.1B	$0.50 - $5.00
Bangkok, Thailand (2022)	$15.1B	$2.3 - $2.7 (80 baht)

Source: INRIX

INRIX released a report that shows the ten most congested urban areas in the United States and their congestion cost. Some cities have congestion prices in the form of time-based tolls, while some do not. Cities that have congestion prices are Chicago ranging from $0.55 - $8.00 (City of Chicago, 2023), New York City ranging from $9.00 - $23.00 (CNN, 2023), San Francisco ranging from $2.17 - $6.50 (San Francisco County Transportation Authority, 2023), and Atlanta ranging from $0.50 - $5.00 (Sporta Report, 2019).

Policy Recommendation: Bangkok Congestion Price

Bangkok's congestion cost is $15.1 billion, which is similar to New York City's $10.2 billion congestion cost. This may be a surprise considering that New York City often ranked higher than Bangkok on the Global Traffic Scorecard (INRIX, 2022). However, it's important to recognize that the congestion cost is calculated far beyond traffic. The number that INRIX calculated may only conclude the traffic cost, gas, and opportunity cost. Our equation considers other important factors such as pollution, noise, and accident cost as well.

When it comes to setting a congestion price, in an ideal world, it would be rational to use a congestion price similar to New York City as this would offset similar costs, similar prices, and, essentially, similar outcomes. However, in reality, every city has a different salary and cost of living. Therefore, it would not be possible to set a congestion price at $9.00 - $23.00 in Bangkok, considering the minimum wage is only ~$10 per day while the minimum wage in New York City is $120 per day ($15 x 8 hours) (NY Department of Labor, 2023). Another research about congestion prices in Bangkok found that the optimal congestion price should be $2.3 - $2.7 (Ayaragarnchanakul and Creutzig, 2022). Ayaragarnchanakul and Creutzig found these numbers by using the market equilibrium model to find the equilibrium price where the marginal social benefits intersect with the marginal private cost. Currently, the price of using the roads and the amount of traffic are not optimal. It only costs $0.68 per kilometer to use the roads, while 256 million kilometers are being traveled each day, creating a deadweight loss. In order to reach the optimal level, the optimal congestion price is recommended to be $2.3 - $2.7 (Ayaragarnchanakul and Creutzig, 2022).

This is a reasonable recommended price for Thailand. However, the current high-way toll in Bangkok is already $0.63 - $3.13 (Expressway Authority of Thailand, 2023). Yet, the traffic doesn't seem to slow down and continues to increase as years go by due to higher demand for private transportation. Therefore, the economic theory would suggest that the price continues to rise until the deadweight loss is eliminated. This price would have to be higher than the current high-way toll which is $3.13, as $3.13 has not been effective.

However, it's important to acknowledge that the wide range and inconsistency of current high-way tolls could contribute to the ineffectiveness of tolls as the lowest price is $0.63, below the recommended optimal price, while the highest price is $3.13, above the recommended optimal price. If the high-way toll in Bangkok is consistently between the recommended optimal congestion price of $2.3 - $2.7, we may see success in imposing a high-way toll to reduce traffic congestion.

III. Conclusion

Congestion pricing, a mechanism wherein drivers are charged a fee for using congested roadways during peak hours, is a proactive approach to reducing traffic congestion. The rationale behind congestion pricing is grounded in the economic theory of negative externality, which highlights the discrepancies between private benefits and social costs. Traffic congestion embodies a negative externality as the private cost of travel does not account for the societal costs including traffic delays, pollution, and reduced productivity.

The extensive analysis conducted in this paper underscores the critical need for the adoption of congestion pricing mechanisms. The equation TCC = TTC + DWL + EC + VOC + RTAC provides a comprehensive framework for assessing congestion costs. Total Congestion Cost (TCC) encompasses components such as Travel Time Costs (TTC), Deadweight Loss (DWL) due to reduced economic efficiency, Environmental Costs (EC) from increased pollution, Vehicle Operating Costs (VOC) attributed to wear and tear, and Road Traffic Accident Costs (RTAC). Applying this equation to the case of Bangkok, Thailand, revealed a staggering congestion cost of $15.1 billion, underscoring the urgency of effective intervention.

To mitigate these costs and rebalance private and social costs, setting an appropriate congestion price is essential. Through analyzing other cities' congestion costs and prices and adjusting for the cost of living, it appears that prices above $2.3 can be effective in reducing traffic congestion. This price not only reflects the actual costs imposed on society due to congestion but also strikes a balance that encourages a behavior shift from private vehicles to public transportation.

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Appendix

Figure 1: Number of new registrations of private cars in Bangkok in Thailand from 2013 to February 2023

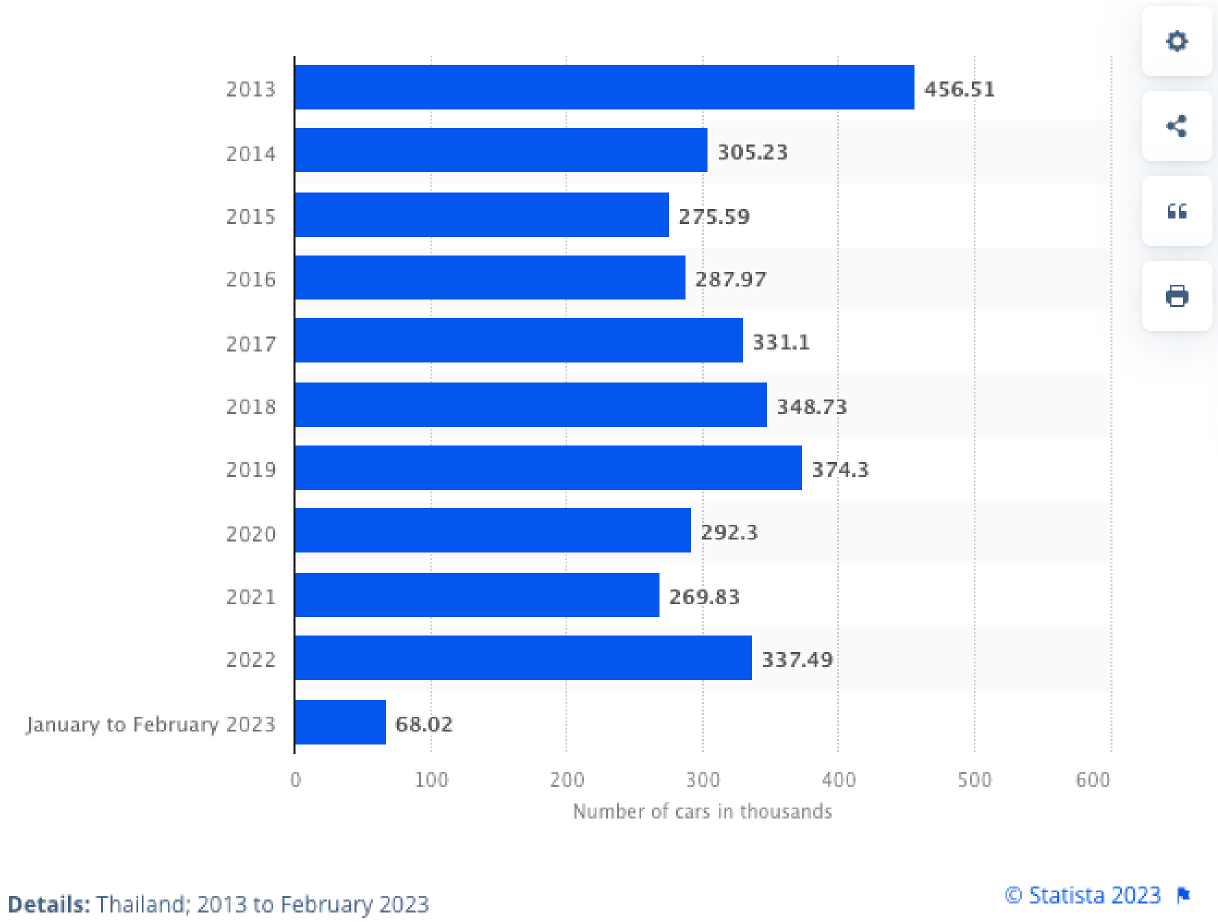

Figure 2: INRIX's 10 Most Congested Urban Areas in the U.S.

Table 1: 10 Most Congested Urban Areas in the U.S.

2022 Rank (2021)	Urban Area	2022 Delay (2021)	Compared to Pre-COVID	Cost per Driver	Cost per City	Change in Downtown Speed (Last Mile)
1 (2)	Chicago, IL	155 (104)	7%	$2,618	$9.5B	-27%
2 (4)	Boston, MA	134 (78)	-10%	$2,270	$4.3B	-27%
3 (1)	New York, NY	117 (102)	-16%	$1,976	$10.2B	-15%
4 (3)	Philadelphia, PA	114 (90)	-20%	$1,925	$4.5B	-15%
5 (5)	Miami, FL	105 (66)	30%	$1,773	$4.5B	-21%
6 (6)	Los Angeles, CA	95 (62)	-8%	$1,601	$8.6B	-17%
7 (7)	San Francisco, CA	97 (64)	0%	$1,642	$2.6B	-14%
8 (13)	Washington, D.C.	83 (44)	-33%	$1,398	$3.5B	-21%
9 (8)	Houston, TX	74 (58)	-9%	$1,257	$3.7B	-16%
10 (10)	Atlanta, GA	74 (53)	-10%	$1,257	$3.1B	-16%

Figure 3: Average Comprehensive Cost by Injury Severity, 2021

Average Comprehensive Cost by Injury Severity, 2021

Death	$12,474,000
Disabling	$1,016,000
Evident	$221,000
Possible injury	$120,000
No injury observed	$17,000

Figure 4: Average Economic Cost by Injury Severity or Crash, 2021

Average Economic Cost by Injury Severity or Crash, 2021

Death (K)	$1,778,000
Disabling (A)	$155,000
Evident (B)	$40,000
Possible (C)	$24,000
No injury observed (O)	$6,700
Property damage only (cost per vehicle)	$5,700