Working Paper 554

Estimation of Productivity Loss Due to Traffic Congestion: Evidence from Bengaluru City

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ESTIMATION OF PRODUCTIVITY LOSS DUE TO TRAFFIC CONGESTION: EVIDENCE FROM BENGALURU CITY

Vijayalakshmi S[1] and Krishna Raj[2]

Abstract

As an economy grows, mobility demand will surge up due to the increased personal income level which is often met by private vehicular ownership. Inadequate infrastructure, especially in a developing country like India, has led to severe traffic congestion, causing huge economic loss. The literature is profound in quantifying the direct economic losses of traffic congestion; mainly, there is an array of research established for estimation of the time cost of traffic congestion. In the effort to estimate the direct costs of traffic congestion, researchers have ignored the impacts of indirect cost, mainly on productivity. Apart from behavioral studies that assess the psychological impact of traffic congestion, there are very few studies which estimate the productivity loss of traffic congestion. The present study has tried to address the issue by estimating the productivity loss due to traffic congestion for a developing country city, Bengaluru. The study estimated loss of productive hours due to the late arrivals caused by traffic congestion would be around 7.07 lakh hours in 2018 for Bengaluru city which would cost around Rs. 11.7 billion. The main cause of the problem can be indicated as supply-side development of road network and there is an urgent need of demand-side management of traffic in the cities of developing countries.

Keywords: Productivity, traffic congestion, time delay, man-hour lost, economic los**s.**

Introduction

Often called as the veins of the economic system, transportation is intricately linked to the productivity of the economy, especially in urban areas. That means, the economic success of any city lies in its transportation system's efficiency; that is how the mobility concerns of a society are met efficiently. Due to this, cities of the world have become engines of economic growth, contributing to the significant part of their nation's income. When we speak of the efficiency of the transport system, it is observed through the unhindered movement of goods and services on an infrastructure network which enhances the economic benefits from increased employment opportunities to wider market access. This infers that any impedance in mobility is bound to cause huge economic losses by reducing the economic productivity.

Impedances in mobility may be the direct cause of the increased demand for travel which has not been met by the transportation system. This gap in demand and supply can be directly linked to agglomeration economies or locational economies. There is extensive literature which has established that cities are the product of agglomeration (Marshall, 1890) which bring larger economies of location like labour availability and cost reduction. Due to this, an uptrend in economic prosperity can be found in cities which have a positive impact on the increased demand for travel. Reacting to this, the demand for travel is often met by private vehicular ownership, causing a major diseconomy (called externality) like traffic congestion which outruns the impacts of economies. This is been observed recently in

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developing countries where the increased demand for travel has not been met by an adequate public transportation network. Further, policy decisions on the transport sector in developing countries like India have not considered the impact of traffic congestion on the economy and hence end up in supply side management of traffic flow which is proved to be inefficient. To elaborate, creating more infrastructure to accommodate increased vehicular population tends to aggravate the problem of traffic congestion, rather than reducing it.

Evidently, cities of developing countries like India with their up surging economic prosperity have created huge pressure on the transportation network and one major by-product of it is traffic congestion. Usually, a major impact of traffic congestion observed by commuters is time wasted or health issues, but there are very few studies which have considered productivity loss caused by slow movement and there are hardly any studies which have accounted for it in the case of India.

Though major cities of India like Mumbai, New Delhi and Kolkata have already become infamous for their snarling traffic situation, and joining this list are southern Indian cities like Bengaluru, Chennai and Hyderabad with their chaotic traffic congestion situation, studies on productivity loss in these cities have not addressed it as an economic loss. The present study tries to fill this research gap. For this, the study selected Bengaluru, one of the major metropolitan cities of the country, and tried to estimate the productivity loss due to traffic congestion here. The major reason of the present paper for selecting the city is the fact that among the metropolitan cities of the country, Bengaluru ranks second in motorization level, next to New Delhi[3] (2017) and in a recent study by BCG (2018) Bengaluru has been ranked as the second city with the worst traffic congestion in the country next to Kolkata, suffering an estimated loss of USD 5.92 billion in 2018.To add to this, among all the cities of the country, it is only in Bengaluru that a major contributor of city's air pollution is linked to vehicular emission (TERI, 2016).

Organization of the paper

The main aim of the present paper is to estimate the productivity cost due to traffic congestion and for this, the paper is organized into four sections: Section I provides a brief contextualization of the issue under concern and literature review; Section II details the study area, data and methodology; Section III provides the estimation of economic cost of productive hours lost and the final section gives the summary and conclusion.

Contextualization of the problem and Literature Review

In transportation economics, time lost due to traffic congestion has attracted special interest mainly because time delayed is money lost and this will have a direct impact on the productivity of an economic activity. Though there are studies which have addressed productivity impacts from the behavioral dimension, the present study differs in its approach, and it is important to provide a conceptual clarity on how the paper will establish its divergence from other studies.

[3] Author estimates using MoRTH 2017 data on registered vehicles in metropolitan cities.

Contextualization of the productivity loss due to traffic congestion

In economics, productivity is generally defined as the ratio of output to the given level of input. This quantitative definition takes different meanings when applied to different factors of production and different fields of study. For example, productivity under the behavioral science field, especially in psychology, mainly depends on the health or stress level which have an impact on mental wellbeing. They evaluate this on the capacity of the labourer to work which is measured as the productivity of that labour. Though there are similar lines of argument in other fields, quantification of productivity differs from one field to another. Hence, it is important for the paper to clearly define the term and the context in which we are measuring productivity.

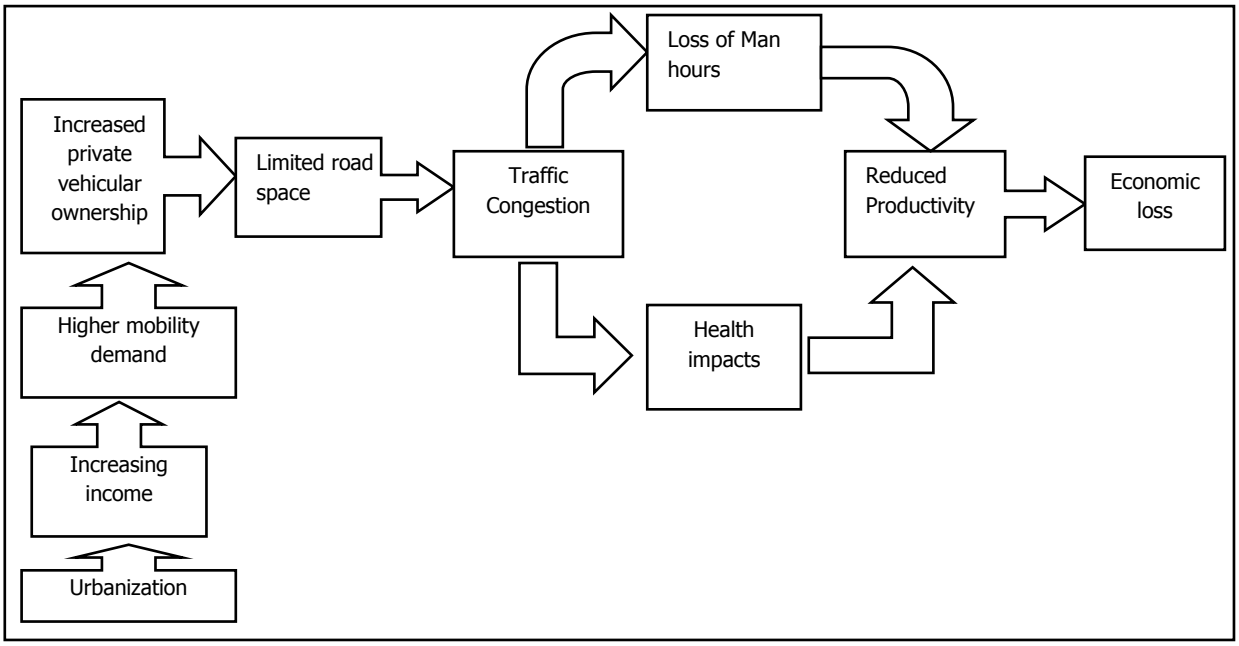
The paper defines the term productivity in the framework of time lost due to traffic congestion. This differs slightly from the traditional economic definition. Further, it is acknowledged by the paper that a congested commute brings huge health implications from stress to cardiovascular issues. But the present paper diverges from this treatment of the problem and analyses more the direct effect of traffic congestion which can be quantifiable.

The paper defines the productivity loss due to traffic congestion is mainly when commuters arrive late to their workplace and substantial productive man hour has been lost. A complete conceptual framework has been established in Figure 1. This provides a glimpse of the impact of traffic congestion on the productivity of commuters. Often overwhelmed by the economic prosperity of an urban area, characterized by increased income levels (product of urbanization), and increased private vehicular ownership, these are not counter supported by the infrastructure developed, more so in the case of developing countries, and lead to slow movement of goods and services or traffic congestion. The dual impact of this will be late arrivals or man hours lost and health impact due to long stay in traffic. The late arrivals or man hours lost is actually productive hours which the commuters could have utilized if they had arrived on time to work.

The estimation of productive hours lost is complex due to lack of data availability and often workers' delayed arrivals are overlooked, for the reason that they can extend their work hours and compensate the loss. While in some workplaces it might be the case where there is an option for flexible work hours, in the primary field investigation for Bengaluru city we found that it may not be true in all cases. Commuters often arrive late to their work place due to traffic congestion but may not extend their work hours, hence leading to productive hour loss. Many times, these losses are overlooked and ignored by the organization[4], but in the long term, the time loss does impose economic loss to both the organization and the economy as a whole. Hence, to provide an insight on the direct impacts of the traffic congestion on the productivity of the commuters, the present paper has estimated the cost of productive hour loss for commuters in Bengaluru.

[4] Organization is used as general term which basically means workplace. It can be government or private sector organization.

Figure 1: Conceptual Framework



Source: Author

Review of Literature on productivity and Traffic Congestion

Traffic congestion has become an inevitable part of everyday urban life (Harriet, *et al*, 2013) and the sad part is, commuters in cities have incorporated the time to be spent in traffic congestion in their daily commute and make arrangements for their departure time. Even after this perceived impact, there are instances where commuters face delays in their travel, leading to productive hours lost in traffic congestion. In their busy urban life, often commuters do not perceive the imputed impacts of time spent in traffic congestion, which has economic losses. Though they perceive traffic congestion as time wasted, we rarely come across any effort to account for the loss in the literature. Crowther *et al* (1963) state that reducing traffic congestion by half will bring huge economic benefit to economies and hence it is important to account for the losses due to traffic congestion.

Although literature identifies the fact that time spent in traffic congestion reduces productivity of individuals (Litman, 2014; Hennessy and Wiesenthal, 1999; Broersma and vanDij, 2008; Novaco, 2018), these studies are either from behavioral aspect of individuals (like stress, health issues) or from the overall gross domestic product of the country. Novaco *et al* (1990) show that chronic exposure to traffic congestion brings health issues and psychological adjustments among commuters which will have an adverse impact on work performance. The article brings out physical impedances and subjective impedances due to stress affected by traffic congestion. The physical impedances can be seen in work absence leading to illness or sick leave and subjective impedances can involve job satisfaction. It is acknowledged that both workers and the work organization incur hidden costs due to traffic congestion, but the paper did not quantify them.

Hennessy *et al* (2000) tried to explore the indicators of stress among drivers and found that the health impact of stress due to congested travel can be linked to high blood pressure, increased

heart rate, frustration and illness. This behavioral study tried to express the qualitative aspects of the problem, but problem but did not estimate the costs attached to it.

There is a diverse array of literature on stress-related research connected with driving and commuting, especially in the field of the psychology of transportation. It has been extensively proved that commuting-related stress arises majorly from the slow movement of vehicles i.e., traffic congestion (Novaco and Gonzalez, 2009; Hennessy and Wiesenthal, 1999; Stokols *et al*, 1978; Gulian *et al*, 1989). Novaco and Collier (1994) in their study on commuters of southern California found that commuting stress is significantly associated with the duration and distance of the commute, controlling for age and income.

Though there are fewer studies which directly addressed productivity impacts due to traffic congestion, some research was found involving macro and firm level analysis. It is argued that regional agglomeration brings increased productivity in terms of gross domestic product. Glaeser *et al* (1992) and Henderson *et al* (1995) proved the employment gains of agglomeration at US metropolitan level. Sveikauskas (1975) and Rigby and Essletzbichler (2002) proved productivity gain for firms being located in a large city. The same results were found for US region by Ciccone and Hall (1996). But in counter argument to these studies, there were some findings which proved that the positive impacts of agglomeration are overruled by negative effects, mainly traffic congestion (Dupont, 2007). The same kind of result was also found by Broersma. L and Jouke van Dij (2008) who used the regional growth accounting approach for eight industries of Netherlands and found that congestion has negatively affected multi-factor productivity, overruling the positive agglomeration effects. This was proved empirically by Baert and Reynaerts (2016), who found that agglomeration would increase productivity by 0.47 percent to 0.56 percent, while traffic congestion would reduce the productivity by 0.55 percent to 0.61 percent and that positive impacts of agglomeration would be overruled by negative impact due to traffic congestion.

From the time delay perspective, the literature has much fewer studies. The impact of late arrivals due to traffic congestion has been a concern in recent years. A study by Harriet *et al* (2013) explores the delay in freight movement in urban Ghana. They point out that delay in delivering time-sensitive logistics can impose additional cost on the company. Another study by Koslowsky *et al* (1995) found that the strain of commuting is associated with increased blood pressure, lower frustration tolerance, increased anxiety and hostility and especially increased lateness, absenteeism and reduced turnover at work.

The quantification of delay cost has been undertaken by Hartgen *et al* (2014) on employees of US and found that 40% of respondents from the survey conducted complain about traffic congestion regularly, particularly as it relates to late arrival to work. The study estimated that $5.3 billion will be lost every year due to shipping delay and $76 billion is the annual cost of employee delay.

From the literature review, it is evident that the impacts of traffic congestion range from health impacts to productivity impacts. Though the problem of traffic congestion has been growing in an alarming rate in cities of developing country like India, studies which account for the loss are still lacking. The present paper is in line with the thought stimulated from the literature review to estimate the cost of late arrivals which has huge impact on productivity of the economy as a whole.

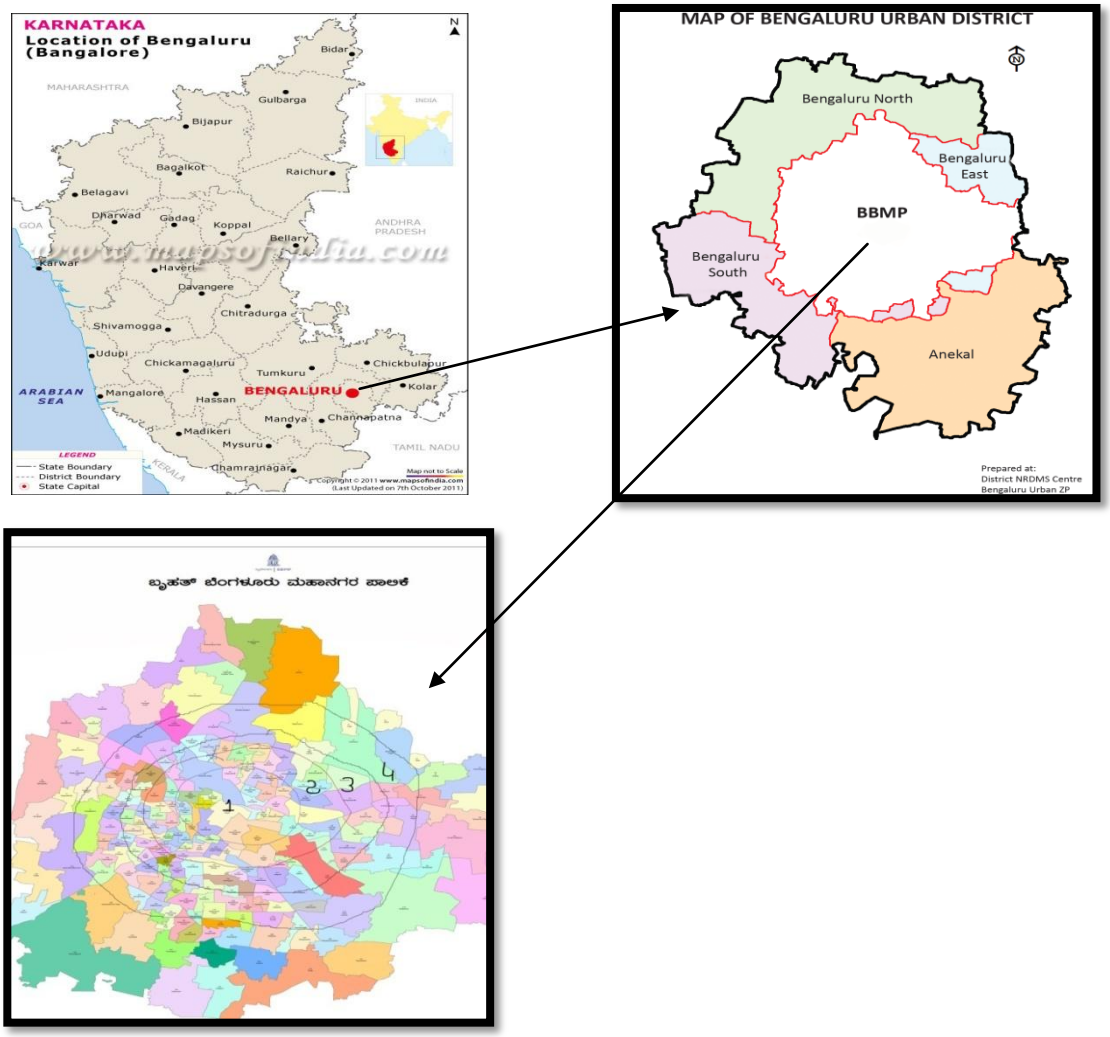
Description of Study Area, Data Collection and Methodology

The study has conducted an estimation of commuters of Bengaluru city, capital city of Karnataka state, India. Bengaluru in recent decades became world famous for its IT sector and renowned as the Silicon Valley and most dynamic city of the world. Being the fifth most populous city of the country (Census, 2011) and second most populous city in terms of automobile registration, the city also became infamous for its traffic congestion. With per capita income growing at 14 percent per annum, vehicles' population growing at 11 percent per annum while the road network is growing at less than 3 percent (2001-15), the city is struggling to accommodate the huge number of vehicles. These factors have majorly contributed to the city being ranked as the second worst congested city in the country by Boston Consultancy Group (2018). In this background, the present study conducted an estimation of the productivity loss of the city commuters when they arrive late to work.

Data collection, Sample size and Sample techniques

Primary data was collected since secondary information is lacking at city level. A multi-stage random sampling method was adopted for the sample selection. At first stage, Bengaluru city was selected and the study restricted to the BBMP jurisdiction of Bengaluru Urban District (BUD). In the second stage, the city was classified into four major zones based on the report of Bangalore Metropolitan Region (BMR) – 2031 published in 2018. From these four zones, 15 high traffic junctions were identified based on the report by the Directorate of Urban Land Transport (DULT), 'Bangalore Mobility Indicators' (2011) which has listed the junctions with traffic signal cycle failure and the findings of the sub-group on Traffic of the Vision Group and Bangalore Traffic Police report (2016), which identified 12 major junctions with volume to capacity ratio (V/c) greater than two (V/C<0.5 is ideal as per IRC, 1990). In these junctions traffic stream stays more than three minutes and causes heavy traffic congestion. This formed the second stage of sampling.

Figure 2: Map of Study area and zone classification



Source: BBMP

The details of zones and junctions identified in each zone are given in Table 1.In Zone 1, that is Central Business District of Bengaluru, three major junctions were identified for the estimation purpose namely Hudson Circle, Corporation Circle and KR Circle. These junctions form the heart of the city and connect the main administrative and commercial centres across the city. Especially Corporation Circle carries heavy traffic as it connects the major commercial hub KR market from the north part of the city.

Zone 2 was classified as adjacent to CBD which includes junctions like Trinity Circle, Richmond Circle, Navarang signal and Okalipuram signal. These junctions are in the business zones of the city. Mainly Trinity and Richmond Circle are the main junctions which carry heavy business traffic of the city. Zone 1 and 2 are of importance to the study as these zones are equipped with metro trains and the field investigation found commuters using metro in these zones.

In Zone 3, the major junctions are Sony World, Magadi Road toll gate, Mekhri Circle and Silk Board flyover signal. Due to the relocation of the city's IT companies in areas like Electronic City and Koramangala, traffic in these junctions has created chaos in the city. The infamous Silk Board signal

connects major IT companies of the city and also carries heavy commercial traffic as it is the main junction through which the city is connected to Hosur.

Zone 4 belongs to the periphery area of Bengaluru which forms the final limit jurisdiction of BBMP. Traffic movement in this area has become a matter of concern due to the expansion of city limits. Major junctions of this zone are: Hebbal flyover signal, KR Puram signal (Tin factory), BEL Circle and Yeshwanthpur signal.

To cover all the sections of the society, a sample of 427 respondents (commuters) was collected. These respondents are from different sectors like government, IT, banks, trade and commerce, self-employed, and informal sector[5]. To have a more representative sample, these sectors were further classified into three levels of positions (senior, middle and lower)[6]. With respect to mode choice, it is evident that Bengaluru has a staggeringly high two-wheeler population. It accounts for 70 percent of the total vehicular population of the city and the sample result is also found in the sample selected. Out of the total sample collected, 63.4 percent of the population uses their private vehicle to commute to work and 36.5 percent use public transportation. Further, in the private mode of transportation, 74 percent of sample respondents use two-wheelers, 25 percent prefer cars and the rest use non-motorised transportation (walk or cycle). Among the total public transportation users, 80 percent of the population uses BMTC buses whereas 16 percent of commuters travel in metro train and the rest prefer their company vehicles. Zonal wise modal choice is provided in appendix 1.

Table 1: Zones and junctions in Bengaluru city

Zone No.	Zone Name	Junctions identified
1	CBD	Corporation Circle, Hudson Circle, KR Circle
2	Adjacent CBD	Trinity Circle, Richmond Circle, Navarang junction, Okalipuram signal
3	Inner Periphery	Magadi road, Mekhri Circle, Sony World junction, Silk Board junction
4	Periphery	BEL Circle, Hebbal flyover, KR Puram junction (Tin factory), Marathahalli bridge signal

Source: Author

The study mainly considered the working section of the population and conducted workplace interviews. The selection of working class was mainly because the regular nature of their commute with a fixed origin and destination every working day. Secondly, it would be convenient to attach an average hourly wage rate to the travel time. The respondents were randomly selected based on the sector, to answer the structured questionnaire. Since the commuter's travel behaviour changes with the mode, a

[5] The definition of informal sector or unorganized sector commuters has been followed from National Commission for Enterprises in the Un-organized Sector (NCEUS). These commuters are mainly workers without any social security benefits from the employer.

[6] First level of employees includes professionals like doctors, chief engineers, professors, general managers, purchase manager, team managers, sales managers, project managers and chief executives;

Second (middle) level employees includes assistant managers, assistant engineers, assistant administrative officers, second division clerks, supervisors, assistant HR, Business associates, floor managers, executive engineers, traffic police constables, operational assistants, senior process managers;

Third (entry) level employees include positions like salespersons, construction workers, carpenters, security guards, street vendors, cleaners, mechanics, petty shop owners, trainees, drivers and service boys. This level also includes informal sector employees.

separate questionnaire for private vehicle users and public vehicle users was used. Among private vehicle users, two major modes were considered: two-wheelers and cars[7]; in public vehicle users, the dominant mode was bus and in recent years, commuters use Metro trains. The study collected data from both modes, but the share of Metro train users was not dominant.

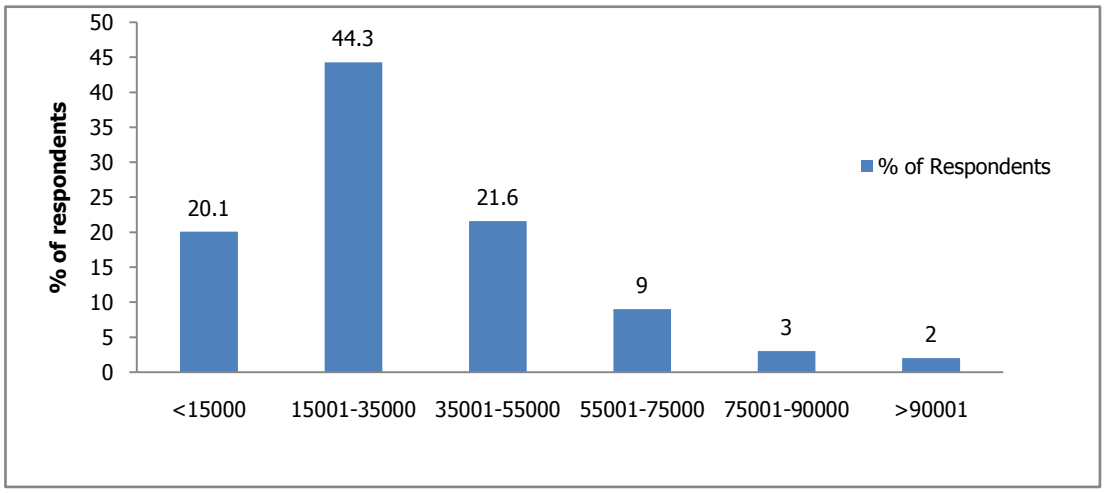
Methodology of the estimation

Since the objective of the paper is to estimate the productive hour lost due to traffic congestion, the study considered the employed section of the commuters in the sample. During the interview, questions were carefully framed to derive the answers on late arrivals and their extension of work hours if any. After close examination of the interview, it was found that there are cases of late arrivals due to traffic congestion and there was no extension of work hours, hence leading to productive hour loss. Those respondents who fit in this scenario were considered for the estimation and their average hourly wage rate was added for every hour lost.

Economic Profile of the Respondents

The economic profile of the study area includes the income level and vehicular ownership of the respondents. The information on income provided in Figure 3 is collected from the primary survey and is specified by the respondents by considering their monthly income from the occupation. This might be considered as the limitation of the study as income may have various sources (other assets).

Figure 3: Income Level of the Respondents (Rs. per month)



The income levels in Figure 5.14 indicate that a majority of the respondents (44.3%) belong to the income group of Rs. 15001- Rs. 35000 per month as on 2018-19. Around 21.6 percent of the respondents belong to the income group of Rs. 35001-55000 and 20 percent belong to less than Rs. 15000 per month. The average income of the sample can be estimated as Rs. 34, 952/month.

[7] Though bicycle is another private mode of transportation, the survey found its usage was less than 1 percent and hence, it is held outside the estimation of time delay cost.

Estimation of Productive Hours Lost due to Traffic Congestion

When a commuter arrives late to the workplace, it is not only a cost for the person, but the productive hours are wasted for the organization also. This is an indirect cost of traffic congestion due to its implied nature, as commuters or organizations tend to overlook the loss due to late arrivals exclusively. There are many studies which acknowledge the fact that traffic congestion reduces the productivity of commuters, but there are hardly any studies which will estimate the loss of productivity.

Often time delay estimates and productive hour lost estimate are considered as overlapping. But to have a clear estimate, the study considered the data of only those respondents who reach their workplace late and do not extend their work hour. From the primary survey, it is observed that some of the private companies would prefer their employees to have flexible hours, but when it comes to late arrival, they manage the productive hour lost by asking the employees to extend their work to cover the lost hour. But when it comes to other sectors like government, banking and allied services, work hour extension is not considered either by employees or employers and neither have they reduced the wages of the employees. This is what is called as implied cost of congestion which is not accounted for explicitly. From the primary survey, it has been found that 57 percent of the private vehicle users and 55 percent of public transport users arrive late to their workplace, leading to productive hour loss as they do not extend the work hour.

Table 2: Productive hours lost due to Traffic Congestion

Zone	Hours lost			Cost per year (Rs.)		
	Private vehicle users	***Public vehicle users***	***Hours lost total***	***Private vehicle users***	***Public vehicle users***	***Total***
1	1632	554	2186	265668	120264	385932
2	1188	576	1764	139104	66816	205920
3	1072	516	1588	138444	87792	226236
4	1428	432	1860	200640	126840	327480
Zonal Total	**4920**	**2078**		**Rs. 7,43,856**	**Rs. 4,01,712**	
Grand Total	**6998 hours per year**			**Rs. 11,45,568 per year**		

Source: Primary data

In Table 2, among the four zones of the city, commuters arriving late to work and complaining about traffic as the cause of it is found in zone 1 and 4. The total loss of productive hour due to traffic congestion can be estimated as 6998 hours a year, leading to a loss of Rs. 11,45,568 per year. To approximate it to the city by assuming 50 percent of the working population would arrive late and may not extend the work hour would lead to 7.07 lakh productive hour loss which costs around Rs. 11.7 billion every year to the city.

An interesting finding from this estimation is that though there is a general tendency among commuters to prefer private vehicles over public vehicles for the reason of it being the fastest mode compared to public transport, the estimation provides a contradictory finding that the commuters who comprise private vehicle users tend to arrive late to the workplace than those who arrive by public

transport vehicles. There might be different implications for this result; it is either because the public transport users tend to perceive the congestion and travel time required and make their travel time arrangement accordingly or private transport users may not perceive such a requirement and face the productive hour loss.

These estimations provide a glimpse of the problem in the city for the policy makers that the queuing up of vehicles in traffic junctions not only causes time delays, but also has a severe impact on the productivity of the economy. The policy makers should aim at providing better public transport infrastructure which has high occupancy, is reliable and faster than the private mode of transportation which occupies much of the road space leading to traffic congestion.

Conclusion

In recent years, a worrying issue for a developing country like India is that thirteen out of twenty Indian cities are facing the worst traffic congestion. The problem of traffic congestion and its impact on productivity for Indian cities is of special interest mainly because it is an area unexplored so far. There are a few studies on traffic congestion in India which have mainly concentrated on time delay estimates using speed-flow techniques rather than productivity impacts on the economy. The present study tried to fill the gap by conducting a primary survey for the city of Bengaluru and estimated the productive hour loss cost of approximately Rs. 11.7 billion in the year 2018 which accounted for 0.027 percent of Bengaluru District's income (2017-18). These estimated numbers may increase as the city progresses and more vehicles are added to the city's road network.

From our estimation, it is clear that traffic congestion imposes a huge economic loss in terms of productivity, and the city planners should aim at resolving this by creating more efficient and sustainable modes of transportation. Demand side traffic management needs to be adopted for the developing cities. The public transport system should be given prominence by city planners and should be reliable and efficient. Further, employers should try to provide flexible working hours for the employees who can then adapt to the traffic movement in the city. It is true that cities are engines of growth, but this growth might be hit by the negative impacts of high traffic leading to productivity loss. Hence, urban planning needs better policy decisions to ease traffic congestion in the cities.

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Appendix 1: Modal choice of the sample respondents (percentage)

Zones	Private vehicle users (%)	Public vehicle Users (%)
1	63	37
2	63	37
3	61	39
4	64	36
Total	**63.4**	**36.5**

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