TRAFFIC CONGESTION'S ECONOMIC IMPACTS:

A SYSTEMATIC LITERATURE REVIEW

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Introduction

Traffic congestion is a universal urban problem and its alleviation has long been a common core transport policy objective (Sweet 2014). There are many reasons for implementing congestion alleviation policies. Assumed negative economic impacts caused by congestion is one of the most common reasons. US federal legislation explicitly identifies congestion reduction and economic support as primary surface transport policy objectives (Sweet 2014). Therefore, in order to formulate more effective policies, it is critical to figuring out how exactly traffic congestion affects the economic performance of cities. However, as a universal byproduct of economic growth, traffic congestion's precise relationship with cities' economic performance is so complicated that researchers haven't entirely explained it or even achieved an agreement on whether congestion stifles the economy.

It is a traditional opinion that traffic congestion is a drag on the economy. Many popular statistics and existing literature support that. For example, recent research on the state of congestion found the total cost of lost productivity caused by congestion to be $87 billion (Fleming 2019). Some research works show that congestion would decrease national(Fernald 1999) and regional (Boarnet 1997; Hymel 2009) economic competitiveness by raising travel costs or increases unreliability (Sweet 2014). On the other hand, more and more research focuses on the complicated relationship between congestion and economic performance. Some researchers argue that even high levels of traffic congestion have no significant negative impact on economic productivity. (Wesley E. and Dumbaugh 2009) Some researchers even believe that traffic congestion is evidence of economic vitality (Brian 2002).

The purpose of this paper would be trying to summarize the consensuses as well as discrepancies among previous research, resolve conflicts among seemingly contradictory previous studies, and cast light on the direction of further research. Firstly, this paper will categorize existing studies according to their focus and provide a synthesis of them. Then, this paper will discuss measurements of congestion. Finally, this paper will display the main findings and try to shed light upon the future study.

Methodology

The purpose of this paper is to synthesize the extant literature and identifies the gaps in the field of congestion's economic impacts. Two kinds of articles are chosen to review in this paper. The first kind of article has a well-developed and representative methodology and a substantial estimation of congestion's economic impacts. Another kind of article might not directly estimate congestion's economic impacts but provide some insights or critics of the existent research method and measurement method. In terms of the study area, this paper mainly focuses on North America. And the articles before 2000 are not chosen because this paper focuses more on recent research rather than the whole history of the research on this topic.

Findings

Economic Costs and Impacts of Congestion

Most substantial studies related to the relationship between congestion and economy can be categorized into two types based on their focus. The first type of research focuses on calculating

the various "costs" of congestion (Weisbro, Vary, and Treyz 2001; Thomson and Bull 2002; Bilbao-Ubillos 2008; Kriger, David et al 2007) Most of this type of academic works set negative impact of congestion on the economy as a default precondition. So, what these works tried to figure out is the extent of traffic congestion's drag on the economy. Rather than holding any default precondition of congestion's impact and calculating the cost, another set of papers directly studied the correlation between traffic congestion and economic performance (Graham 2007) (David T and Gregory 2009) (Hymel 2008) (Dumbaugh 2012) (Sweet 2014) (Jangik and Rafferty 2017) (Wesley E. and Dumbaugh 2009). Among this set of studies, some of them found no connection (Sweet 2014) or even positive relationships (Dumbaugh 2012; Wesley E. and Dumbaugh 2009) between congestion and some economic indicators.

Economic costs of congestion

Based on the idea that traffic congestion stifles economic growth, many transportation planning practices are focused on managing or eliminating traffic congestion (Dumbaugh 2012). According to the Texas Transportation Institute(TTI), vehicle delay costs Americans $115 billion in wasted fuel and time each year. While there is no doubt that increasing traffic congestion does impose costs upon not only travelers but also the whole society and the environment, it is difficult to measure the direct or indirect costs caused by congestion. Therefore, the research on the economic costs of congestion is very necessary for benefit-cost analysis of urban congestion reduction strategies (Weisbro, Vary, and Treyz 2001).

Weisbrod, Vary, and Treyz (2001)'s study focuses on the congestion's economic costs to business. Their study applied data from Chicago and Philadelphia to examine the congestion's impact on business costs, productivity and output level. The theory behind is the congestion could shrink business market areas and reduce the "agglomeration economies". According to their

approach, the congestion costs include travel costs, additional business operating costs, and productivity costs. Among these three types of costs, travel cost and additional business operating costs are direct costs of congestion while productivity cost is congestion's further impacts on the economy. This relatively complete representation of the real monetary cost of congestion is an important contribution of this study. And because of the more complete measurement of costs, the partial results of this study imply potentially higher costs of congestion than those reported in the TTI analysis.

Prejudicial effects are also an important feature of congestion. Thomson and Bull(2002) pointed out that besides car drivers, public transport users also suffer a lot from the worse condition caused by congestion, even though they do not cause congestion. Bus passengers not only suffer from longer journey times but also higher bus fares because more units and drivers are required to provide the same transport capacity.

In Kriger, Miller, Baker, and Joubert(2007) 's research, a model-based approach replaced the widely used comparative analysis and was applied to quantify congestion and its cost in the nine largest urban areas in Canada. This travel demand-forecasting model's application "provides a basis for linking the engineering aspects of congestion with the broader economic perspectives". In this study, the cost of congestion includes the costs of delays, wasted fuel, additional costs because of the increased use of vehicles, accidents, and environmental damage. The results showed that the time value of delay comprises the largest component, about 90%, of the total cost of congestion.

Bilbao-Ubillos' paper provided an even more complete frame of estimating the costs and welfare loss caused by congestion so that public-sector decision-makers could make more informed congestion reduction strategies. They first identified both private costs and social costs.

Private costs included driver's time lose, risks of accident, and stress while social costs included pollution, noise, risks from hazardous freight transport and the barriers created by busy streets. However, as Thomson and Bull(2002)'s study showed, bus passengers also lose time and money because of congestion. But they were ignored in this study.

Although many scholars are dedicated to developing a more practical and complete measurement of congestion's total cost, some dispute the concept of the 'total cost of congestion' (Goodwin 2004). Goodwin believes that the concept of 'total cost of congestion' is based on comparing a real-world condition with unrealistic world with free-flow speeds. Therefore, the number of total cost of congestion is practically meaningless. On the other hand, the marginal costs brought about by a specific feasible project or act of policy matters more in practical terms than total costs.

Table 1 Economic Costs of Congestion

Reference	Area	Methodology	Measure of Congestion	Measure of Cost
Weisbrod, Vary, and Treyz 2001	Chicago, Philadelphia	Economic Model elasticity of substitution	Travel Delay (TTI)	Travel Cost Additional Business Operating Costs Productivity
Thomson and Bull 2002	Brazilian cities		Travel Delay (TTI)	people's time and vehicle operating costs bus users time and fares
Bilbao-Ubillos, Javier 2008			Travel Delay (TTI)	Financial costs and welfare losses Environmental costs and loss of welfare
Kriger, David et al 2007	Canada	travel demand-forecasting models	Travel Delay (TTI)	delay wasted fuel greenhouse gas emissions

Economic impacts of congestion

The economic performance of cities has fascinated economists and regional scientists for centuries. There are extensive studies and empirical evidence on the positive role of transportation in improving regional economic performance (David T and Gregory 2009). However, before 2005,

researchers have devoted less effort to identifying congestion's broader economic impacts (Hymel 2008), and the role of traffic congestion in influencing metropolitan economic activity is complex and unclear (Taylor 2002). The reason is that large regional economies usually benefit from agglomeration externalities (Graham 2007) and at the same time lead to more congestion, which may impede economic activities by degrading mobility services (Sweet 2014). Therefore, some scholars began to doubt or dispute the generally established belief that congestion is an economic drag. Some papers even conclude that congestion is an indicator of a healthy urban economy (Staley 2012). The most recent efforts hence have attempted to capture the precise relationship between regional performance and traffic congestion and transportation system performance.

In a study of London, Graham (2007) investigates the link between congestion, density, and economic productivity by sector (Graham 2007). In order to measure the effect of urban congestion on agglomeration, 'Effective density' based measures of agglomeration were constructed. These measures capture the amount of 'activity' that is accessible from some given location. The accessibility is represented by distance and the generalized cost of road travel which information both about distances and road speeds. In this way, congestion factors were connected with the agglomeration and hence the economic productivity. Finally, he found congestion to constrain agglomeration externalities and diminish return for some business sectors such as manufacturing, construction, distribution, and information technology but be positively associated with others such as real estate, banking and finance, business services, and personal services.

In a 2009 study of 8 cities in the U.S., Professor David Hartgen (2009) also investigated how accessibility impacts economic performance (David T and Gregory 2009). According to their definition, accessibility is the number or percentage of jobs or residents within a given drive time from a point, which is slightly different from the 'Effective Density' in Graham's study. In terms

of economic performance, this study used gross regional product per worker as measurement. For the results, he found that a 10 percent decrease in CBD accessibility would decrease regional productivity by about 1 percent. This study also found that reducing congestion would boost Gross Regional product by 6 to 30 percent if targeted at suburbs, malls, and universities; the economic gains would be 4 to 10 percent if targeted at CBDs, and just 2 to 8 percent if targeted at airports. These findings hence suggested a rethinking of congestion reduction strategies, particularly in non-CBD locations.

In another pertinent study, Hymel (2009) estimates how traffic congestion casually impacts employment growth by using a cross-section of U.S. metropolitan areas (Hymel 2008). The endogeneity issue was extensively discussed in this study. In this case, endogeneity means that there could be some persistent and unexplained factors that affect both employment growth and congestion, which makes isolating the causal effect become difficult. To address this issue, two instrumental variables were used in the regression, the number of radial road miles and a measure of MSA(Metropolitan Statistical Area)'s historical influence on transportation policy. This study found that congestion dampens subsequent employment growth and the dampening effect is nonlinear and more intense in highly congested places. Based on his findings, Hymel called for "expanding road capacity" or implementing "congestion pricing" to reduce traffic congestion and benefit employment growth.

Another similar study was made by Sweet (2014). In addition to job growth, he also examined how traffic congestion impacts worker productivity. In order to better address endogeneity issue, Generalized method of moments(GMM) estimators are used, and several instruments are designed. Besides those instruments adopted from Hymel (2009) and Boarnet (1997), "a count of the number of beltways planned according to the US interstate plan" is also

employed. Unlike other studies only using travel delay as a measurement of congestion, this study also measured congestion using the average daily traffic per freeway lane(ADT). The results of this study suggested that higher levels of congestion-induced travel delay are expected to negatively impact job growth but not productivity growth. But Sweet also acknowledged that no MSA in the US has approached the threshold. For worker productivity, there was no statistically significant relationship with traffic congestion. Sweet hence concluded that "economies do not stagnate as a consequence of traffic" (Sweet 2014).

Based on the methodology developed by Hymel (2009) and Sweet (2014), Marshall and Dumbaugh (2018) assess the association between traffic congestion and gross domestic product (GDP) per capita; jobs; and per capita income(PCI) via 30 years of data for the largest 100 U.S. metropolitan statistical areas. For instrumental variables, Marshall and Dumbaugh (2018) the underlying premise is less about funding as Hymel(2009) and Sweet(2014) suggested and is more about the idea that "regions with high levels of congestion may have a higher level of representation" (Wesley E. and Dumbaugh 2009). Therefore, this study used the number of congressional representatives on transportation & infrastructure committee as well as transportation-related land consume as instrumental variables. They also used a different measurement of congestion, "percent of peak VMT under congested conditions", because they believed that work-related commuting travel coincides more with peak period traffic congestion. However, freight obviously wasn't taken into consideration in this measurement. The results of this study suggested that traffic congestion is positively associated with economic outcomes at least at the MSA level. Based on their findings, Marshall and Dumbaugh (2018) called for a focus shift from macro-scale congestion relief towards more salient economic and transportation concerns (Wesley E. and Dumbaugh 2009).

Meanwhile, another study made by Jin and Rafferty (2017) also sought to explore the relationship between congestion, income, and employment at the MSA level but suggested totally different results. They found that traffic congestion growth negatively affects income growth and employment growth (Jangik and Rafferty 2017). The different methods they used in this study might lead to diverging results. Rather than using instrumental variables in regression, this study found another way to explain the interrelationship between traffic congestion, employment, and income, systems of simultaneous equations. And a Three-Stage Least Square(3SLS) was employed to estimate the simultaneous model. In addition to the congestions' negative effects on both income growth and employment growth, Jin and Rafferty also found that "higher road capacity does not guarantee a reduction in traffic congestion" (Jangik and Rafferty 2017).

Table 2 Economic Impacts of Congestion

Reference	Area	Methodology	Measure of Congestion	Measure of Economy
Graham, Daniel J. 2007	UK	regression analysis	effective densities (accessibility)	total factor productivity (TFP)
David T and Gregory 2009	8 cities in U.S.	"equilibrium" traffic models	accessibility	Gross Regional Product
Hymel 2009	U.S. metropolitan areas	panel data model instrumental variable	Travel Delay (TTI)	employment growth
Dumbaugh 2012	U.S. metropolitan areas	regression analysis	Travel Delay Per Capita	regional GDP per capita
Sweet 2013	U.S. metropolitan areas	panel data model instrumental variable	Travel delay / ADT(average daily traffic (ADT)per lane on average)	employment growth productivity growth per worker
Jin and Rafferty 2017	U.S. metropolitan areas	simultaneous equation model Three-Stage Least Square (3SLS)	Travel Delay (TTI)	income growth employment growth
Wesley E and Dumbaugh 2018	U.S. metropolitan areas	panel data model instrumental variable Durbin-Wu-Hausman tests for endogeneity	percent of peak VMT under congested conditions	per capita gross domestic product (GDP) job growth per capita income

Measures of Congestion

In view of traffic congestion itself has long been a prominent topic, a great deal of effort has been devoted to developing a comprehensive set of congestion measures. There are several different ways to measure congestion. According to Weisbrod, Vary, and Treyz's study, these measures can be grouped into five categories: time-related measures, volume measures, congestion indices, delay measures, and LOS measures and the most commonly used measurement is the travel delay index that can be obtained from the Texas Transportation Institute(TTI) (Weisbro, Vary, and Treyz 2001). One key reason is that it is directly related to the time loss, the direct cost of congestion. Travel delay index is the aggregate amount of time lost due to congested driving conditions, and this measure using the difference between free-flow and average actual speeds on individual highway segments at different times of day (Schrank and Lomax 2006). Although the travel delay index has been used in most congestion's costs and impacts related studies over the years, its disadvantage is undeniable. First, the 'target' world with present traffic and free-flow speeds in this measure logically cannot exist because the amount of traffic would increase with the elimination of congestion (Goodwin 2004). Second, in some cases given by Goodwin's (2004) study, this measure of congestion is internally inconsistent. For instance, if we deliberately increase or reduce the 'target' speed, according to this measure, the congestion would be more or less even the real congestion doesn't change (Goodwin 2004).

Many recent studies employed some different measurements of congestion. In some academic works, congestion's impacts were included via the measure of accessibility (Graham

2007; David T and Gregory 2009). Sweet(2013)'s study measured congestion using the average daily traffic per freeway lane(ADT). "Percent of peak VMT under congested conditions" was used as a measure of congestion in Marshall and Dumbaugh (2018)'s study. On the one hand, as shown in Sweet(2013)'s study, different measures could provide a better understanding of congestion's impacts on the economy by adding a new dimension. After all, congestion itself is a complex phenomenon. It is unrealistic that congestion can be described by only one index. However, on the other hand, the various measures also lead to different or even contradictory results. The robust, usefulness and comparable of the results could be diminished because there is no consistent measurement of congestion.

Discussion

Along with the growth of urban areas across the world, rising traffic congestion is an inescapable condition, and it keeps getting worse regardless of attempted remedies. In addition to the widespread complains, congestion alleviation to prevent regional economic stagnation also justifies many expensive transport programs. Even though congestion has been generally regarded as a heavy drag on economic growth for a long time, the precise relationship between congestion and economic growth is still unclear. In order to make better informed benefit-cost analysis for congestion alleviation strategies, it is necessary to figure out the congestion's costs or impacts on economy. However, the endogeneity issue relying on dual causation makes it challenging to isolate the real relationship between congestion and economic growth. And the complexity of congestion itself makes the research even harder.

Most of the current research can be grouped into two categories. Those studies in the first category dedicated to estimating the negative impacts of congestion by developing a complete

frame to calculate congestion's cost. The reviewed literature suggests that the total cost of congestion is practically useless for informing the congestion reduction strategy due to the internally inconsistent measure of congestion (Goodwin 2004). The marginal cost of traffic congestion thus merits more research. Furthermore, the discussion about the interrelationship between congestion and economic performance is rare in this category. Taking agglomeration externality into calculation might provide more practical results.

Another set of papers attempts to directly figure out the relationship between traffic congestion and economic outcomes. Many statistical methodologies were employed to address the endogeneity issue, such as instrumental variables and simultaneous equation model. However, the results usually differ from each other's because of the different statistical methods and different measures of congestion they used. Most results support the idea that congestion has negative impacts on the economy (Graham 2007) while some results show that economic growth could be not related (Sweet 2014) or even positively associated with congestion (Wesley E. and Dumbaugh 2009). There is also a big gap in applying these approaches on the local level rather than the metropolitan level (Wesley E. and Dumbaugh 2009). Almost all of the studies in this category only use the data at the MSA level.

In this paper, we also discussed the different measures of congestion used in studies: travel delay, accessibility, ADT, percent VMT. There is one more appealing than others. Designing a desirable set of measures of congestion also remains a major research challenge.

Conclusion

The goal of this paper is to synthesize the extant literature and identifies the gaps in the field of congestion's economic impacts. Most results support the idea that congestion has negative impacts on the economy while some results show that economic growth could be not related or even positively associated with congestion. The reviewed literature suggests that the precise relationship between congestion and economic growth is still unclear. Extant research mainly focuses on either congestion's total cost or the relationship between regional economy and congestion. For the former, the marginal cost of traffic congestion and agglomeration externality merits more research. For the later, more effort could be dedicated to estimating congestion's economic impact at the local level. Designing a desirable set of measures of congestion also remains a major research challenge. To conclude, despite the fact that the research in the field of congestion's economic impacts has accelerated, this outline and review gives some new research directions for future study.

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