Received: 24 June 2020 | Revised: 23 February 2021 | Accepted: 30 April 2021

DOI: 10.1111/grow.12499

ORIGINAL ARTICLE

growth and change WILEY

Measurement and analysis of neighborhood congestion: Evidence from sidewalk pedestrian traffic and walking speeds

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Funding information
USDA National Institute of Food & Agriculture, Grant/Award Number: Hatch Multistate Grant # ME 031808 (NE 1749)

Abstract

Regional scientists and planners are interested in congestion, both vehicular and pedestrian. This paper examines pedestrian congestion on sidewalks in the tourism district of Bar Harbor, Maine, with a focus on the effects of cruise passengers. The analysis considers pedestrian counts and the effects of passengers on walking speeds. Cruise passengers increase sidewalk pedestrian traffic overall, but the effects on walking speeds are mixed. For both indicators of sidewalk congestion, cruise passenger impacts decrease at greater distances from the passenger point-of-entry into Bar Harbor. The methods presented in the paper can be applied to sidewalk congestion related to a wide range of facilities and events (e.g., transportation hubs, museums and concert halls, sporting events, large pilgrimage events).

1 | INTRODUCTION

Congestion can take on a lot of different forms. At the scale of a large city or metropolitan area, congestion can be represented by commuting times and the number of vehicles on a region's roadways (Broersma & van Dijk, 2008; Sweet, 2014). Past studies have examined the connection between congestion and the structure of urban areas (Gordon et al., 1989; Smeed, 1968; Tsekeris & Geroliminis, 2013). Likewise, researchers have analyzed the efficacy of using tolls to combat urban disamenities such as traffic congestion and sprawl (Anas & Rhee, 2006; Arnott, 1998; Leape, 2006; Small, 1983). At a much smaller scale of a neighborhood, congestion can be represented by the number of vehicles and pedestrians that cross a busy intersection or even the number of people walking along a particular stretch of sidewalk. Cities such as New York, San Francisco, Seattle, and Las Vegas experience crowded sidewalks, particularly in places around transportation hubs and major attractions

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such as Fisherman's Wharf in San Francisco and New York's Fifth Avenue between 54th and 55th Streets (Blumenberg & Ehrenfeucht, 2008; Hu, 2016).

The everyday lives of local residents, people who walk to work, and the presence of cyclists and skateboarders contribute to sidewalk congestion. In places that attract tourists, the activities of visitors can further increase levels of pedestrian traffic. The combination of local residents and tourists using sidewalks, along with street performers and outdoor seating in sidewalk cafés (Kim et al., 2006), can create hotspots of sidewalk congestion. And just as the number of tourists in a region often varies by month of the year and time of day, these factors and a place's proximity to attractions and transportation hubs are expected to influence the number of people walking along the sidewalk.

This study examines congestion at the neighborhood level, with a focus on sidewalk pedestrian traffic and walking speeds. The specific application is an analysis of the effects of cruise passengers on congestion in Bar Harbor, Maine's tourism district. The research questions addressed by the study are:

1. What are the impacts of cruise passengers on sidewalk pedestrian traffic and walking speeds?
2. To what extent are the impacts of cruise passengers on sidewalk pedestrian traffic and walking speeds moderated by a stretch of sidewalk's distance from where they enter and depart from port?

These questions are motivated, in part, by a local ordinance that sets a limit of no more than 3,500 passengers allowed per day in July and August, which is Bar Harbor's peak season for non-cruise ship tourism. The paper looks at a local policy experiment that involved a one-day lift of the summertime passenger cap. Namely, the town allowed the *Anthem of the Seas*, with a capacity of 4,180 passengers, to visit the port on August 27, 2018. Results of the analysis are used to estimate the impacts on sidewalk congestion in Bar Harbor's tourism district due to the additional 680 passengers permitted on that day.

2 | RELATED LITERATURE

Sidewalk congestion is often analyzed in terms of pedestrian level-of-service (LOS) (Dixon, 1996; Polus et al., 1983; Zacharias, 2001). Pedestrian LOS is defined as an indicator of operational conditions within a pedestrian traffic stream (Transportation Research Board, 2000). It is influenced by the sidewalk's capacity, quality of the walking environment (e.g., architectural interest, pedestrian signals), and the pedestrian's perception of comfort, safety, and security (Landis et al., 2001; Raad & Burke, 2018). Along with its impact on pedestrian LOS, sidewalk congestion influences the walkability of neighborhoods, which is related to the health of residents and the local environment (Creatore et al., 2016; Frank et al., 2006).

Fruin's (1971) seminal study of pedestrian LOS examined the relationships between the volume of pedestrians on sidewalks, the amount of sidewalk space between pedestrians, and walking speed. The research used time-lapse photography at specific points on the sidewalk, which allowed for precise measurement and modification of sidewalk characteristics. Study findings show that higher pedestrian volumes are associated with less space between pedestrians, and a reduction in space is associated with slower walking speeds. Mōri and Tsukaguchi (1987), who also found that an increase in pedestrian density is associated with a reduction in walking speed, suggest that a focus on sidewalk capacity and related measures such as walking speed are "suitable" for the analysis of congested sidewalks due to heavy pedestrian traffic. In our analysis of sidewalks in Bar Harbor, we use a similar approach that

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examines the effects of cruise ships on the number of people observed while walking on the sidewalk, as well as impacts on walking speed.

This study builds from a rich literature in regional science about congestion in cities and metropolitan areas (Anas & Rhee, 2006; Arnott, 1998; Gordon et al., 1989; Small, 1983; Tsekeris & Geroliminis, 2013), but its focus on congestion in neighborhoods is novel. Our analysis at this scale of geography responds to a call by Ellen and O'Regan (2010) for more research by regional scientists on neighborhoods.[1] To date, regional scientists have studied a variety of issues related to neighborhoods, such as crime, gentrification, residential sorting, school quality, and housing (Aaronson, 2001; Bell & Machin, 2013; Boehm & Ihlanfeldt, 1986; Brueckner & Rosenthal, 2009; Clark & Herrin, 2000; Helms, 2003; Ioannides, 2004; McMillen, 2008; Rosenthal, 2008). For many research questions, knowing the amount of activity on sidewalks and how it varies by time of day and proximity to key landmarks are important considerations in the study of neighborhoods.

This paper is also one of the first econometric-based studies to analyze the determinants of sidewalk pedestrian traffic, and how congestion translates into slower walking speeds. Much of the existing research on sidewalk congestion focuses on how to measure it, and many previous studies use various types of descriptive analyses to characterize pedestrian traffic (Dixon, 1996; Fruin, 1971; Landis et al., 2001; Raad & Burke, 2018). The econometric approach outlined in the paper allows us to isolate the effects of cruise passengers on sidewalk congestion. A similar approach could be used in other places to examine the impacts on neighborhood congestion associated with a wide range of local attractions and events.

In addition, this paper contributes to the literature on the behavior of cruise passengers while in port (Andriotis & Agiomirgianakis, 2010; De Cantis et al., 2016; Ferrante et al., 2018). Most closely related to this study, Jaakson (2004) examined the idea of a "tourist bubble" by analyzing the parts of town that cruise passengers explore. Jaakson (2004) employed an observational method of counting pedestrian flows, similar to the data collection approach used in our analysis, in a study of cruise passengers in Zihuatanejo, Mexico. Descriptive analysis of the data shows that 7 of the 16 areas considered experience more than 50 percent higher pedestrian traffic flows when ships are in port, whereas the impacts of cruise ships are much smaller in other parts of town. The areas with the largest percentage increases in pedestrian traffic tend to be located close to where passengers get off the ship, which suggests that impacts decrease at greater distances from the point of entry.

3 | BAR HARBOR AND CRUISE PASSENGERS

Bar Harbor, which is similar to many coastal towns and national park gateway communities, provides an excellent setting for the study of sidewalk congestion. The town has a compact and walkable tourism district that is characterized by streets lined with restaurants, bars and shops, several parks, and residential housing.[2] Figure 1 is a map of Bar Harbor's tourism district with a few streets and landmarks identified. The distances listed in the figure are measured between the landmarks and Harbor Place (marked with a star).[3] The Town Pier and Harborside are also noted on the map. Most cruise passengers take a tender from the ship to Harbor Place and some take one to a pier near Harborside. Some small ships dock at the Town Pier and passengers walk on and off ships directly without tendering. The two most distant landmarks shown (Havana restaurant and Hannaford supermarket) are located near the outskirts of Bar Harbor's tourism district, which are about 2,700 and 2,200 feet, respectively, from Harbor Place.

The region's main visitor attraction is Acadia National Park, which brings substantial numbers of tourists to Bar Harbor during the summer months. These visitors to Acadia National Park, along

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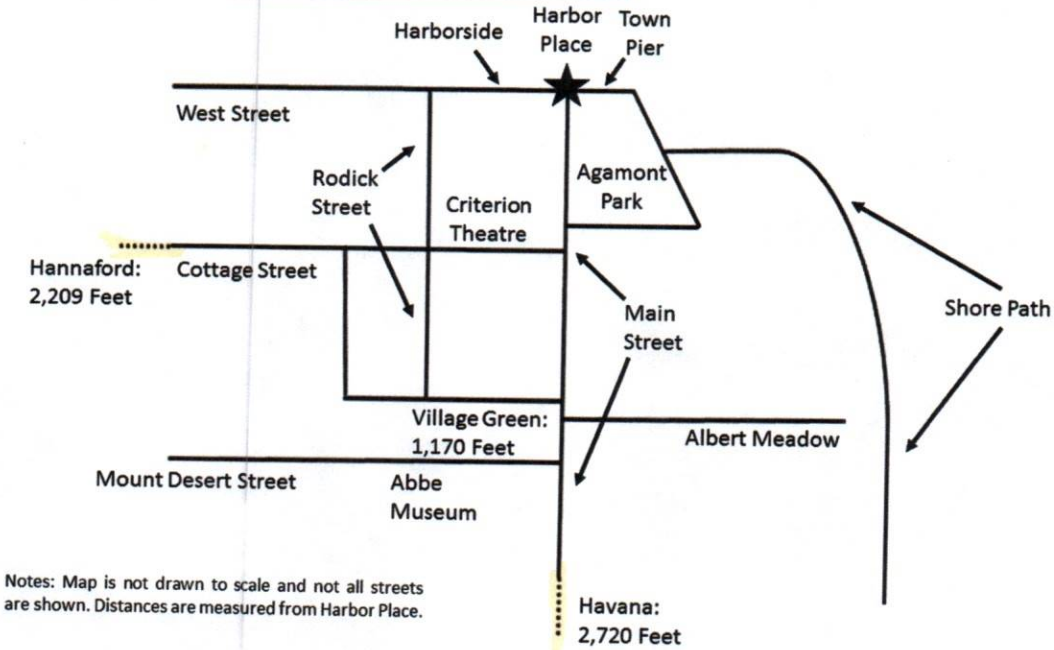

FIGURE 1 Map of Bar Harbor's tourism district

with cruise passengers in the fall and a small year-round resident population, account for most of the pedestrian traffic in Bar Harbor's tourism district. The high seasonality of tourism in the area (e.g., 43 percent of Acadia National Park use happens in July and August) contributes to a wide variation in the number of pedestrians observed in Bar Harbor's tourism district at different times of the year.[4] These seasonal trends aid in establishing a baseline level of sidewalk pedestrian traffic related to a particular day, which helps to isolate the additional pedestrians associated with cruise ships.

Most of the land-based visitors to Bar Harbor use automobiles as the mode of transportation, as the entire state of Maine is characterized as a "drive" tourism market. After arriving in town, visitors can explore the tourism district by foot and, to access Acadia National Park, people can drive their own vehicles or use a free seasonal bus service. Most of the streets in the tourism district have parallel parking spots, either on one or both sides of the street. To address local concerns about parking, which are more apparent during the summer, Bar Harbor installed seasonal parking meters after the time period covered by this study. The traffic patterns in the tourism district vary widely from a steady stream of vehicles in the peak summer season to very light traffic in the offseason.

Cruise passengers are an ideal segment of visitors to examine the effects of tourists on sidewalk congestion. Unlike land-based tourists that arrive and depart at all times of the day, cruise passengers follow a set schedule that allows us to know the approximate number that could be in town. Likewise, given that cruise passengers enter and depart from port at a specific location (De Cantis et al., 2016), we know the distance that passengers have to cover to reach all parts of Bar Harbor's tourism district. This type of information is not typically known for land-based tourists. Finally, since cruise passengers arrive by ship and very few rent automobiles, the majority of these visitors explore Bar Harbor's tourism district by foot. This means that cruise passengers directly contribute to pedestrian traffic in an area.

Bar Harbor had a scheduled 180 cruise ships visit in 2018, with a combined capacity of about 250,000 passengers. Most cruise ships came to Bar Harbor during the months of September (one-third

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of passengers in 2018) and October (30 percent of passengers), as part of autumn New England and Atlantic Canada itineraries. Unlike cruise passengers that mostly visit in September and October, a large percentage of land-based tourists come to Bar Harbor in August and July.[5] Bar Harbor's popularity as a summertime tourism destination is presumably a motivating factor behind the town's cruise passenger cap in July and August.

Most of the cruise passengers access the tourism district and the area's sidewalks by crossing West Street from Harbor Place (or the Town Pier or Harborside) to the corner of West Street and Main Street. From there, a large percentage of the passengers explore the tourism district by walking on the sidewalks along Main Street in the direction of Cottage Street and the Village Green Park. Land-based tourists and local residents access the sidewalks in a variety of ways. The tourism district has several lodging establishments, which provide direct access to overnight visitors who wish to explore the area on foot. Day visitors and local residents primarily access the area and its sidewalks from a parking spot along one of the streets or a parking lot.

4 | EMPIRICAL ANALYSIS AND RESULTS

A two-part empirical method examines the relationship between walking speed and the number of people encountered while walking on a stretch of sidewalk, and then the effects of cruise passengers on sidewalk pedestrian traffic. Both parts of the analysis use data collected from 2,031 sidewalk pedestrian counts observed in Bar Harbor's tourism district between July 2017 and December 2018. Jaakson (2004) used a similar approach of counting people while walking on a sidewalk, which is a method referred to by Burton and Cherry (1970) as the "principle of the moving observer," to examine the idea that cruise passengers stay in a "tourist bubble" while in port. More generally, past research examining pedestrian level-of-service has used indicators related to the attributes of sidewalks, pedestrian flow such as walking speed and space between people, and the subjective walkability ratings of pedestrians (Fruin, 1971; Landis et al., 2001; Maghelal & Capp, 2011; Petritsch et al., 2006; Raad & Burke, 2018).

The specific data collection approach used in this study involved a researcher walking between two arbitrary points and counting the number of pedestrians who are walking in the opposite direction and the number of people walking in the same direction that the researcher walks past. From this count, we subtract the number of people that "overtook" the researcher by walking at a faster pace. This method is then repeated by walking between the same two points in the opposite direction.[6] Having observations collected by walking in both directions allows for a calculation of an average amount of pedestrian traffic on the sidewalk covered between the two points.

Since the two points used to count pedestrians can be spaced at different distances apart, it is necessary to measure the distance between the two points and use this value to scale the count of pedestrians.[7] This is because, other things being equal, the number of pedestrians observed increases with the distance over which the counts are measured.[8] Along with counting the number of people observed, the researcher also logged the amount of time it took to walk between the two points. This information is used, combined with the distance between the two points, to measure walking speed. Although the observations on pedestrian traffic and walking speeds provide a novel way to examine sidewalk congestion, the data collection method has several disadvantages such as being "labor intensive and time consuming," and inherent limits "to the accuracy of counts of people… and subjectivity in the interpretation of data" (Jaakson, 2004). Jaakson (2004, p. 50) notes, and this caveat applies to this study as well, that "there is a fine line in the analysis" of this type of research "between rigid factual reporting and exploratory interpretation of observations."

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Figure 2 shows the distribution of pedestrians encountered per 100 feet while walking along sidewalks in Bar Harbor's tourism district. The 2,031 observations were collected between 7 a.m. and 10 p.m. over 66 different days, and across the entire tourism district shown in Figure 1. The pedestrian counts were observed in all types of weather conditions (e.g., a low temperature of 1-degree Fahrenheit on January 1, 2018) and at times when the sidewalks were treacherous due to accumulations of ice and snow. The observations shown in Figure 2 and used in the regression analysis are weighted by day of the week (i.e., weekend versus weekday), season of the year, time of day, and location in Bar Harbor's tourism district.

The figure shows sidewalk pedestrian counts of fewer than one person per 100 feet in about one-half of the observations. These data points were mostly collected at times early in the morning, during months outside the peak tourism season and in inclement weather, or at places located on the outskirts of the tourism district. At the other end of the spectrum, about 20 percent of the observations had pedestrian counts of five or more people per 100 feet, with many of these observations collected on Main Street during the summer months. Overall, the distribution is skewed to the right with a weighted average sidewalk congestion of 3.09 people observed per 100 feet (standard deviation of 5.19 people per 100 feet).

Table 1 shows OLS regression results on the effects of sidewalk congestion on walking speeds, as measured by a 50-year-old male researcher while conducting the pedestrian counts. Across all 2,031 observations, the researcher had an average walking speed of 4.88 feet per second with a standard deviation of 0.76 feet per second. This is faster than the 50th percentile walking speed (4.75 feet per second) of a person between 31 and 60 years old when crossing an intersection and slower than the average speed (4.96 feet per second) of a male between 14 and 64 years old (Fitzpatrick et al., 2006).

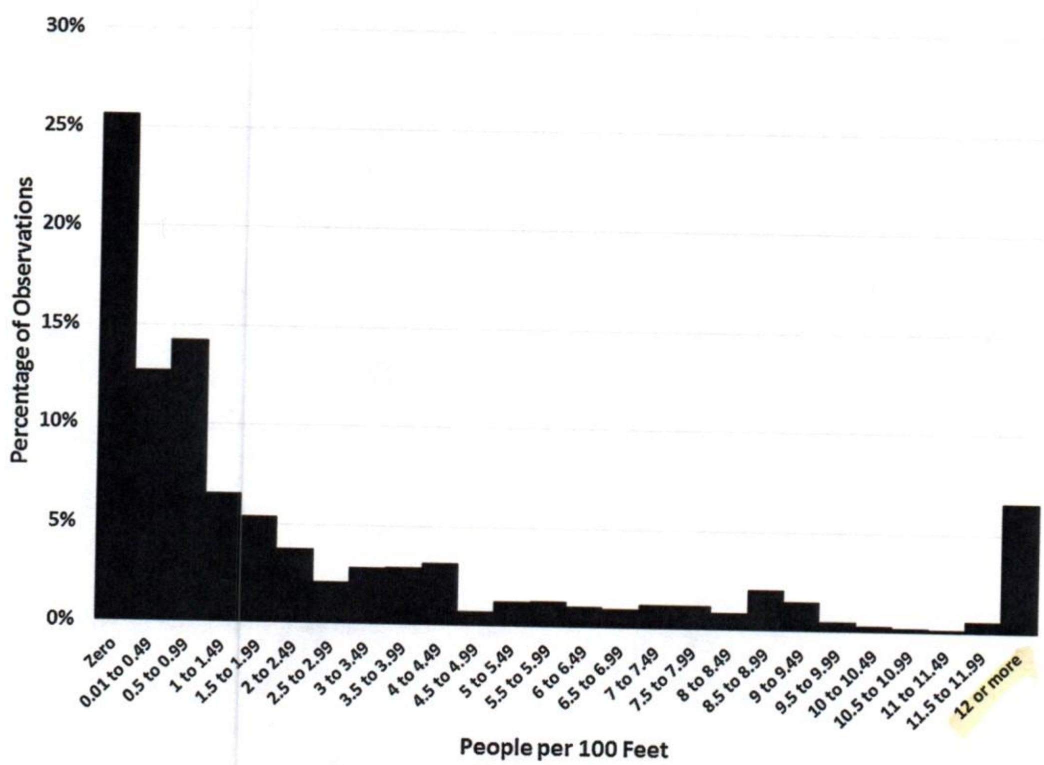

FIGURE 2 Pedestrians counted per 100 feet of Bar Harbor sidewalks

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TABLE 1 OLS results: Effects of sidewalk congestion on walking speeds ($n = 2{,}031$)

Variable	Estimated coefficient	Standard error
Constant	5.145***	0.038
People per 100 Feet	−0.076***	0.004
Treacherous Sidewalks	−0.610***	0.143
Raining	−0.122	0.082
Snowing	0.104	0.253
R^2	0.280	

Notes: The dependent variable is walking speed measured in feet per second. The superscript *** indicates statistical significance at a 1-percent level. The second column of results shows robust standard errors.

The average walking speed of 4.88 feet per second translates to about 3.33 miles per hour or 148.7 centimeters per second, which is within a 95-percent confidence interval (112.2 to 149.1 centimeters per second) of the walking speed of males aged 50 to 59 years old (Bohannon & Andrews, 2011).

Along with a measure of the number of people observed per 100 feet, the regression model also has variables indicating the weather condition (i.e., rain or snow) when the observation was collected and a separate variable indicating whether the sidewalk had treacherous walking conditions due to ice or snow from current or past precipitation.[9] Similar to the results of Fitzpatrick et al. (2006), Fruin (1971), and Mōri and Tsukaguchi (1987), the regression results show that an increase in the number of people encountered on the sidewalk is associated with a reduction in walking speed. Other results suggest that current weather conditions do not affect walking speeds, whereas pedestrians tend to walk slower on snow- and ice-covered sidewalks.

Figure 3 shows the estimated effect of sidewalk congestion on walking speeds, with the other variables in the model set at values, indicating that it is not raining or snowing and that the sidewalk is not treacherous from current or past precipitation. The regression results imply an estimated walking speed of 4.91 feet per second at the average congestion level of 3.09 people encountered per 100 feet and that it would require a more than 400 percent higher congestion level to reduce walking speeds by 20 percent. This suggests that, at an average level of pedestrian traffic, Bar Harbor's sidewalks can accommodate considerably more people without substantially lowering walking speeds. These results, summarized in Figure 3, are used later in the paper to measure the extent to which cruise passengers reduce pedestrian walking speeds.

The second part of the empirical analysis examines the effects of cruise passengers on sidewalk congestion, where the dependent variable is the number of people encountered on sidewalks per 100 feet walked. In this analysis, the dependent variable is adjusted to a uniform walking speed of 4.88 feet per second, which is the average pace across all observations, to account for the interrelationship between congestion and walking speeds.[10] This adjustment allows for an evaluation of the effects of cruise passengers on congestion that is not influenced by the fact that, other things being equal, a slower pace provides more time to encounter pedestrians while walking on the sidewalk.

The explanatory variable of main interest is the capacity of the ship(s) in port, which is scaled to 100s of passengers in the regression model. Of the 2,031 observations, 841 were logged when one or more ships were in port. Across the entire sample, the average number of cruise passengers in Bar Harbor is 800, with a standard deviation of 1,485. To isolate the effect of cruise passengers on sidewalk pedestrian traffic, the regression models have variables that control for the time of day (five dummy variables, with between 1 p.m. and 4 p.m. as the omitted category that is excluded in the regression model).[11] The models also include dummy variables indicating the street where the observation was

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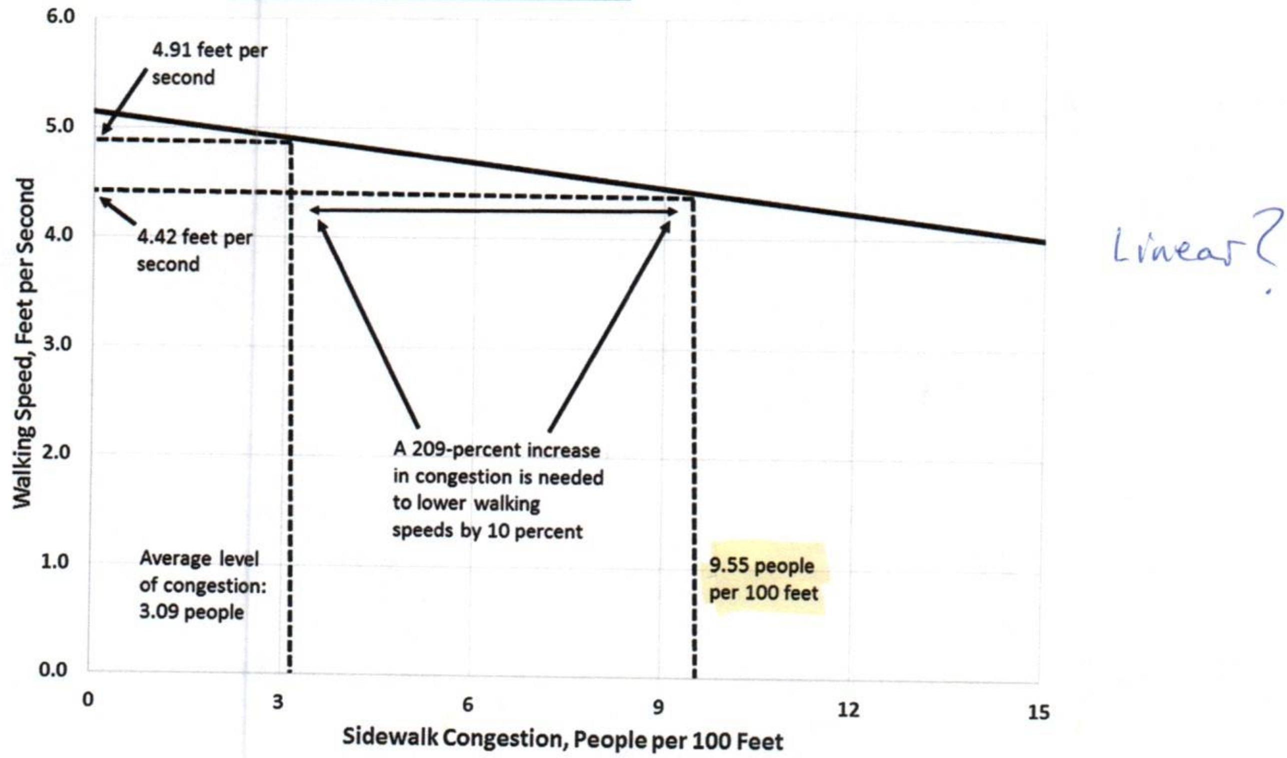

FIGURE 3 Effect of sidewalk congestion on walking speeds

recorded (four dummy variables, with places in the tourism district other than Cottage, Main, and West Streets as the omitted category to which the other dummy variables are compared).[12]

In addition, the regression models have a variable measuring the distance between Harbor Place and where the observation was logged, as well as a variable that measures the interaction between the number of passengers in port and distance from Harbor Place. The distance from Harbor Place (mean of 1,145 feet, with a standard deviation of 579 feet) is measured relative to the midpoint of the stretch of sidewalk covered when counting the number of pedestrians. The estimated coefficient corresponding to the interaction term shows the extent to which passenger impacts peter out at greater distances from where they enter Bar Harbor. Finally, the regression models include dummy variables indicating the day when the observation was collected. As noted earlier in the paper, the 2,031 observations were logged over 66 different days, and the day-specific dummy variables account for all of the non-cruise ship factors that might affect sidewalk pedestrian traffic on a particular day.

In the regression models with the day-specific dummy variables, the impact of cruise passengers on sidewalk pedestrian traffic is identified by differences, within a given day, in the number of passengers. For example, a day with a cruise ship in port could have observations from before its arrival and after its departure. In addition, the data set includes observations from days when Bar Harbor hosted multiple ships with staggered arrival and departure times. A day with multiple cruise ships in town could have observations with zero passengers in port before or after the visits and differences in the numbers of passengers throughout the day.[13] Comparing observations with and without ships from a single day, with variables in the model that controls for time-of-day and location impacts identified from the entire sample of observations, provides a very "tight" set of controls for isolating the impacts of cruise passengers.

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TABLE 2 OLS results: Effects of cruise passengers on sidewalk pedestrian traffic ($n = 2{,}031$)

	Estimated coefficients			
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant	4.675*** (0.383)	3.896*** (0.396)	0.938 (0.658)	0.020 (0.618)
Cruise passengers, 100s	0.087*** (0.006)	0.178*** (0.015)	0.079** (0.033)	0.165*** (0.035)
Distance from harbor place	−0.002*** (0.0001)	−0.002*** (0.0002)	−0.002*** (0.0001)	−0.001*** (0.0001)
Passengers is × Distance	NA	−0.00008*** (0.00001)	NA	−0.00008*** (0.00001
7 a.m. to 10 a.m.	−2.690*** (0.303)	−2.723*** (0.303)	−2.167*** (0.368)	−2.406*** (0.365)
10 a.m. to 1 p.m.	−1.533*** (0.310)	−1.539*** (0.307)	−0.784** (0.313)	−0.846*** (0.311)
4 p.m. to 7 p.m.	1.193* (0.662)	1.315** (0.666)	0.469 (0.430)	0.520 (0.442)
7 p.m. to 10 p.m.	3.171*** (0.727)	3.233*** (0.718)	1.567** (0.725)	1.397* (0.735)
Main street	2.400*** (0.218)	2.334*** (0.213)	2.160*** (0.181)	2.091*** (0.173)
Cottage street	0.953*** (0.298)	1.017*** (0.298)	1.111*** (0.234)	1.160*** (0.233)
West street	−0.353 (0.353)	−0.246 (0.334)	−0.291 (0.303)	−0.185 (0.291)
Day-specific dummy variables	No	No	Yes	Yes
R^2	0.466	0.494	0.662	0.694

Notes: The dependent variable is the number of people encountered per 100 feet. The superscripts ***, **, and * indicates statistical significance at a 1-percent, 5-percent, and 10-percent level. Robust standard errors are shown in parentheses.

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TABLE 3 OLS results: Effects of cruise passengers on walking speeds ($n = 2{,}031$)

Variable	Estimated coefficients			
	Model 1a	Model 2a	Model 3a	Model 4a
Constant	4.772*** (0.110)	4.863*** (0.111)	5.471*** (0.293)	5.571*** (0.289)
Cruise passengers, 100s	−0.004 (0.002)	−0.014*** (0.003)	−0.003 (0.006)	−0.013** (0.006)
Distance from harbor place	0.0002*** (0.00004)	0.0001* (0.00004)	0.0001*** (0.00004)	0.00005 (0.00004)
Passengers × Distance	NA	0.00001*** (0.000002)	NA	0.00001*** (0.000002)
7 a.m. to 10 a.m.	0.318*** (0.083)	0.322*** (0.083)	0.080 (0.106)	0.106 (0.107)
10 a.m. to 1 p.m.	0.217*** (0.080)	0.217*** (0.080)	0.036 (0.101)	0.042 (0.099)
4 p.m. to 7 p.m.	0.024 (0.113)	0.010 (0.114)	−0.123 (0.100)	−0.128 (0.100)
7 p.m. to 10 p.m.	−0.258** (0.112)	−0.265** (0.112)	−0.192 (0.121)	−0.173 (0.121)
Main street	−0.388*** (0.082)	−0.380 (0.082)	−0.353*** (0.079)	−0.346*** (0.079)
Cottage street	−0.173* (0.095)	−0.180* (0.094)	−0.240*** (0.092)	−0.245*** (0.092)
West street	−0.267** (0.110)	−0.279** (0.110)	−0.207** (0.095)	−0.219** (0.095)
Day-specific dummy variables	No	No	Yes	Yes
R^2	0.123	0.133	0.280	0.290

Notes: The dependent variable is walking speed measured in feet per second. The superscripts ***, **, and * indicates statistical significance at a 1-percent, 5-percent, and 10-percent level. Robust standard errors are shown in parentheses.

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Table 2 shows regression results on the effects of cruise passengers on sidewalk pedestrian traffic. The first model, which does not include the set of dummy variables indicating the day the observation was collected, has variables that control for the number of passengers in port, time of day, street where the observation was recorded, and the distance between where the observation was recorded and Harbor Place. The second model includes these same explanatory variables and a variable that measures the interaction between the cruise passenger and distance variables. The third and fourth models add the day-specific dummy variables.

The regression results from all four models show a positive and statistically significant relationship between sidewalk pedestrian traffic and the number of cruise passengers in Bar Harbor. The results from model 3 show that a 100-passenger increase in the capacity of ships in port is associated with a 0.08 increase in the number of pedestrians encountered per 100 feet walked at a speed of 4.88 feet per second.[14] This impact can be thought of as an "overall" effect of cruise passengers on sidewalk congestion across the entire tourism district.[15] The results from model 4 show that the effects of cruise passengers on sidewalk pedestrian traffic decrease at greater distances from Harbor Place. This is similar to the findings of Jaakson (2004), who also found lower impacts of cruise ships at greater distances from the point of entry. At 250, 500, 1,000, and 1,500 feet away, the estimated impacts per 100 cruise passengers are 0.14, 0.12, 0.08, and 0.04 increases, respectively, in the number of pedestrians observed per 100 feet. The effect of cruise passengers on sidewalk congestion is "zero" at about 2,000 feet from Harbor Place. When walking on Main Street, this distance is about the halfway point between the Village Green Park and Havana restaurant (see Figure 1).

The estimated coefficients from model 4 show that other things being equal, sidewalk pedestrian traffic is higher during the hours of 4 to 7 p.m., and 7 to 10 p.m., as compared with the hours of 1 to 4 p.m. Other results show that Main and Cottage Streets experience more sidewalk congestion as compared with areas in the tourism district that are not located on Cottage, Main, and West Streets. The day-specific dummy variables indicate substantial variation in sidewalk pedestrian traffic over the course of the year, with higher amounts of people walking the sidewalks on summer days than during the rest of the year. For example, the dummy variable indicating observations collected on August 4, 2017, has an estimated coefficient of 10.2 (t-statistic of 7.25), compared to an omitted category of observations logged on December 30, 2017, when the temperature was 10-degrees Fahrenheit. Likewise, a dummy variable indicating observations from July 3, 2017, has an estimated coefficient of 7.6 (t-statistic of 6.10). These results are consistent with the strong seasonal patterns of tourism and economic activity in Bar Harbor.

Results from the two-part analysis can be used to estimate the effect of cruise passengers on sidewalk walking speeds. The estimates from model 3 show that an additional 100 passengers in port increase sidewalk congestion by 0.08 people per 100 feet. A 0.08-increase in the number of people observed per 100 feet, using the results presented in Table 1, lowers walking speeds by 0.006 feet per second. This effect of cruise passengers on walking speeds, interpreted as an "overall" impact across the entire tourism district, is very small. Estimates from model 4 show that an additional 100 passengers in town lead to 0.14, 0.12, 0.08, and 0.04 higher levels of pedestrian traffic at 250, 500, 1,000, and 1,500 feet from Harbor Place. Increases in sidewalk congestion of 0.14 (at 250 feet) and 0.08 (at 1,000 feet) additional people observed lower walking speeds by 0.011 and 0.006 feet per second. This shows that the impacts of cruise passengers on walking speeds decrease at greater distances from Harbor Place.

As a robustness check to these findings from the two-part analysis, Table 3 shows results from regressions that have walking speeds as the dependent variable and the same sets of explanatory variables used in the analysis of sidewalk pedestrian traffic. The estimates from model 3a, which do not account for the interaction between the number of passengers and distance from Harbor Place, do not

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show a statistically significant relationship between walking speeds and the number of passengers in Bar Harbor. This result is similar to the very small impact from the two-part analysis and suggests that the presence of cruise passengers does not affect walking speeds when considered across the entire tourism district.

The results from model 4a, however, show that cruise passengers lower walking speeds in Bar Harbor, but these effects peter out at greater distances from Harbor Place. For example, the regression results suggest that an additional 100 passengers in town decrease walking speeds by 0.010 and 0.004 feet per second at 250 and 1,000 feet from Harbor Place. This pattern of a reduction in impacts at greater distances from where passengers enter port is qualitatively similar to the estimates (0.011 and 0.006, respectively, at 250 and 1,000 feet) from the two-part analysis. The estimated coefficients from model 4a suggest that the effect of cruise passengers on walking speeds is "zero" at about 1,400 feet from Harbor Place, which is 30 percent closer than the estimated distance of about 2,000 feet at which the impact of cruise passengers on the sidewalk pedestrian traffic is "zero."

5 | EFFECTS OF LIFTING THE PASSENGER CAP ON AUGUST 27, 2018

As discussed in the introduction, Bar Harbor limits the size of cruise ships allowed in July and August to vessels with combined capacities of no more than 3,500 passengers per day. The reasoning behind this cruise passenger cap is, presumably, the already high levels of congestion in and around Bar Harbor's tourism district associated with non-cruise ship tourists and visitors to Acadia National Park. Bar Harbor lifted the passenger cap on August 27, 2018, as an experiment to study its effects.[16] On this date, Bar Harbor hosted the *Anthem of the Seas*, which has a capacity of 4,180 passengers.

The results of the regression analysis can be used to estimate the impact of this one-time exception to the cruise passenger cap. Although the demonstration project exceeded the cap by 680 people, this general approach could be used to estimate the impact of any-sized ship visiting Bar Harbor on any particular day. The results from model 3 in Table 2 suggest that an additional 680 cruise passengers in Bar Harbor are associated with a 0.53 increase in the number of pedestrians encountered while walking 100 feet. This is interpreted as an "overall" impact across the entire tourism district. Using the results from model 4 in Table 2, we estimate that an additional 680 passengers would increase sidewalk pedestrian traffic from 11.1 to 12.1 pedestrians per 100 feet walked at 250 feet from Harbor Place, 10.1 to 11.0 people at 500 feet from Harbor Place, and 8.1 to 8.7 people at 1,000 feet from Harbor Place.[17] These effects translate into 8.8, 8.3, and 7.0 percent higher levels of sidewalk congestion with the larger ship, compared with a baseline of a vessel holding exactly 3,500 passengers.

We can also examine the effects of an additional 680 cruise passengers on pedestrian walking speeds, which vary at different distances from Harbor Place. Figure 4 shows that, at a distance of 250 feet from Harbor Place, having 4,180 passengers in port allows for a walking speed of 4.23 feet per second.[18] This is 1.7 percent slower than the walking speed of 4.30 feet per second estimated at the cap of 3,500 cruise passengers. The estimated walking speed with 4,180 cruise passengers is 9.8 percent slower than the estimated walking speed with no ship in port, and 14.0 percent slower than the walking speed under the sample average of 3.09 pedestrians encountered. The slower walking speed of 4.23 feet per second with a ship holding 4,180 passengers is influenced by the presence of the ship and the fact that sidewalks are more crowded during the summer months. Of the entire reduction in walking speed from 4.91 to 4.23 feet per second, about 77 percent of the slowdown is due to the presence of the ship and the remaining 23 percent is attributed to the time of year when the ship visited Bar Harbor.[19]

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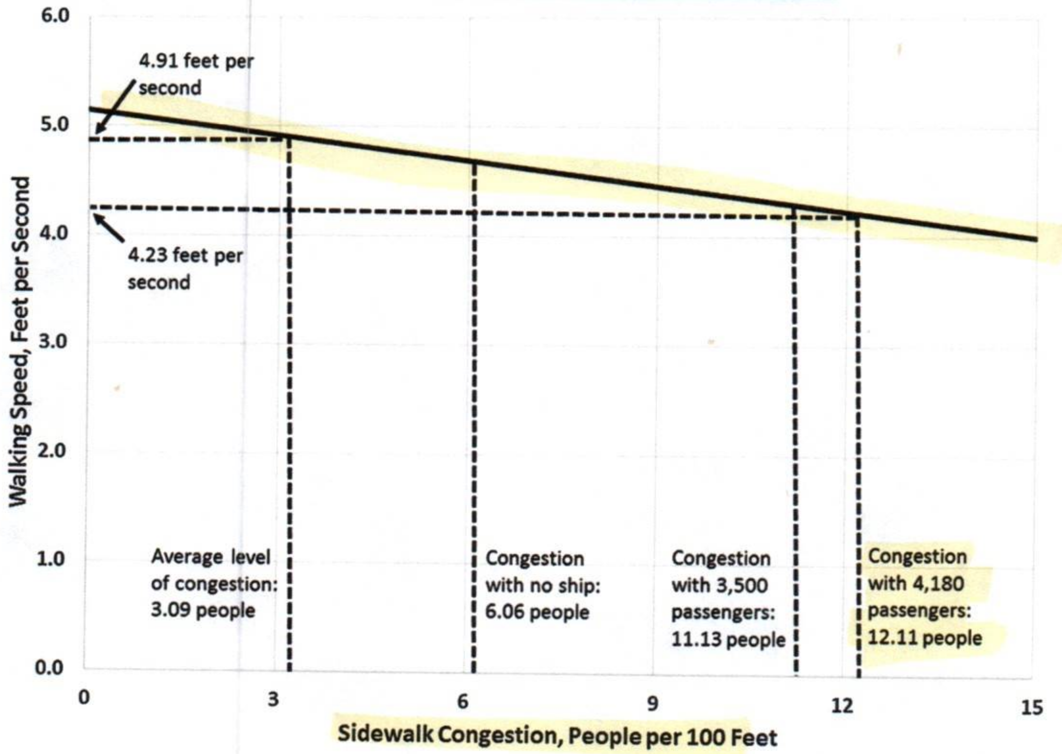

FIGURE 4 Walking speeds at 250 feet from Harbor Place on August 27, 2018

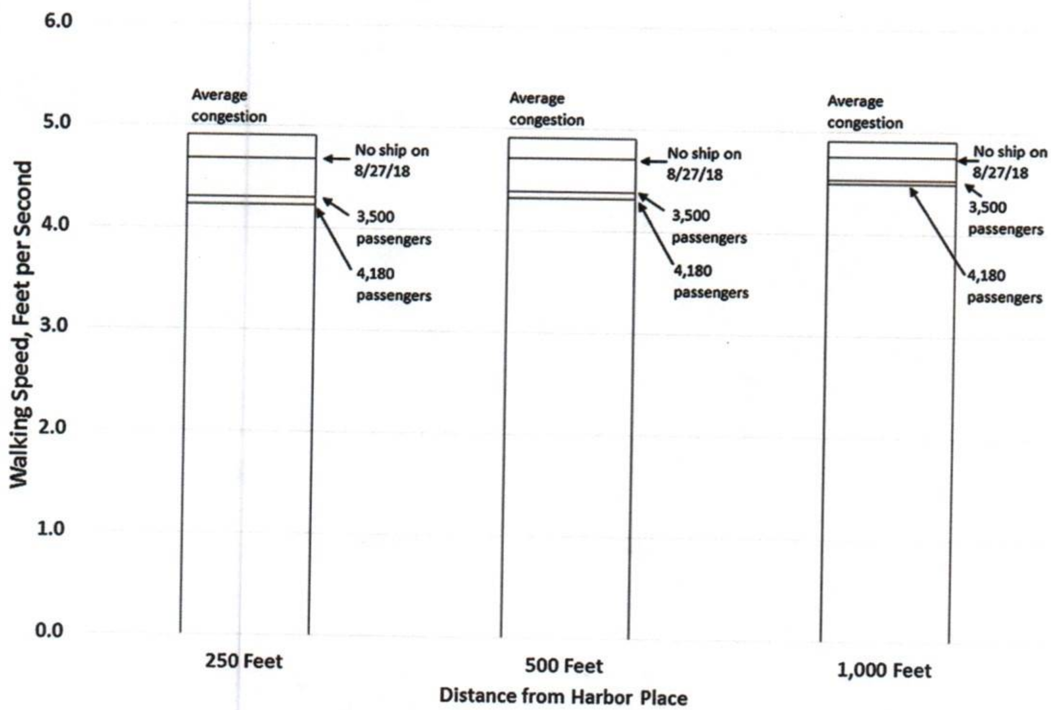

FIGURE 5 Effects of cruise ships on walking speeds: August 27, 2018

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Figure 5 summarizes results on the effects of exceeding the cruise passenger cap on August 27, 2018, at various distances from Harbor Place. For example, at a distance of 1,000 feet, the estimated walking speed with 4,180 cruise passengers in port is 0.9 percent slower than the walking speed at the passenger cap of 3,500 passengers, and 5.5 percent slower than the walking speed with no ship in port. Likewise, at 500 feet from Harbor Place, there is a 1.5 percent reduction in walking speed associated with a 680-person increase (i.e., from 3,500 to 4,180) in the number of cruise passengers.

6 | CONCLUSIONS

Regional scientists and planners are interested in the causes and consequences of congestion. Considerable research has examined congestion at the scale of a large city or metropolitan area, using indicators such as commuting times and the number of vehicles on a region's roadways (Anas & Rhee, 2006; Arnott, 1998; Gordon et al., 1989; Small, 1983; Sweet, 2014). This paper analyzed congestion at a much smaller scale of a neighborhood, with a focus on sidewalk pedestrian traffic and walking speeds. Specifically, this study examined the effects of cruise passengers on congestion in Bar Harbor, Maine's tourism district, along with an analysis of a local policy experiment that lifted a summertime cruise passenger cap on a single day in August of 2018.

To revisit the research questions posed at the beginning of the paper, the results show that cruise passengers increase sidewalk pedestrian traffic overall, but the effects of passengers on walking speeds are mixed. For both indicators of congestion, cruise passenger impacts decrease at greater distances from the passenger point of entry into Bar Harbor. Pertaining to the town's "demonstration project" that allowed a one-day exception to the summertime cruise passenger cap, our analysis shows that the *Anthem of the Seas* contributed to almost twice as much sidewalk pedestrian traffic, compared with a no-ship baseline on August 27, 2018, at 250 feet from where passengers enter the port. This increase in sidewalk congestion resulted in 9.8-percent slower walking speeds at 250 feet from the passenger point of entry. The ship's impact on pedestrian level-of-service decreases to a 5.5-percent reduction in walking speeds at 1,000 feet from the point of entry, and the ship's impact on walking speeds is "zero" at about 1,400 feet from where passengers enter the port.

In addition to these results specific to Bar Harbor's one-day policy experiment of exceeding the summertime cruise passenger cap, the analysis revealed several general findings that are important to the study of sidewalk congestion. First, our assessment of congestion differed depending on the indicator used. Specifically, we found that the number of people observed on sidewalks is more sensitive than pedestrian walking speeds at detecting differences in congestion. Second, the analysis showed large impacts on congestion associated with the street of observation and distance from where the passengers entered the town. These results are not surprising, however, given the importance of location and distance to the study of regions and the idea that "neighborhoods are ultimately microregions, so the theories and tools used to study" regions apply to neighborhoods as well (Ellen & O'Regan, 2010, p. 376).

Third, our analysis revealed impacts on sidewalk congestion that are associated with the time of day and the exact day when observations were measured. This demonstrates the utility of our approach at capturing the "ebb and flow" of economic activity at a very micro level, but also suggests that relative impacts on sidewalk congestion depend on exactly when they occur. For example, in our study of cruise passengers, a ship carrying 4,180 passengers would have a larger relative impact, compared with a "no-cruise ship" baseline, in October than in July, because the amount of sidewalk congestion without a ship is generally lower in October than in July.

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The methods used in this paper can be applied to the study of congestion elsewhere and inform research on other topics related to neighborhood change and regional planning. Although this study used observations covering 18 months, this type of information could be collected over a longer time horizon to examine more gradual patterns of neighborhood change.[20] In a large city or metropolitan area, sidewalk pedestrian traffic and walking speed data could be collected in multiple neighborhoods at a single point in time to examine differences across places. Finally, although our analysis focused on cruise passengers, the methods could be applied to the impacts of a wide range of facilities and events (e.g., transportation hubs, museums and concert halls, sporting events, large pilgrimage events) that attract people to an area.[21]

Ideas for future research include examining preferences for sidewalk pedestrian traffic, analyzing the impacts of sidewalk congestion and walking speeds on individual behavior, and examining the impacts of sidewalk congestion on people with different levels of mobility. Pertaining to preferences, laboratory experiments could use videos and pictures of different levels of congestion to determine optimal levels of pedestrian traffic. Preferences might vary with individual characteristics such as age and are likely to differ between tourists, local residents, and business owners.

Pertaining to the impacts of sidewalk congestion and walking speeds on behavior, some local residents may avoid parts of the tourism district during the summer months and times when ships are in port. The slower walking speeds experienced during the summer, however, could encourage more "window shopping," which might affect the probability that a pedestrian enters a shop or restaurant. Finally, an extension to the analysis could look at the relationship between sidewalk pedestrian traffic and walking speed for a senior adult, or someone in a wheelchair. The current project used data collected by a single researcher, which eliminates some sources of variation related to differences in walking speeds across people, but it also limits our ability to say how sidewalk pedestrian traffic might impact others.

ACKNOWLEDGEMENT

The author thanks Dan Rickman and the anonymous reviewers for excellent comments provided on an earlier draft of the paper. Gabe's research program is supported, in part, by Hatch Multistate Grant # ME 031808 (NE 1749) from the USDA National Institute of Food & Agriculture. The dataset used in this project is available at the Maine Dataverse Network website: http://dataverse.acg.maine.edu/dvn/faces/study/StudyPage.xhtml?globalId=hdl:TEST/10282&versionNumber=1

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ENDNOTES

1 Mulligan (2014) includes "neighborhood change" as a promising "new direction" for research in regional science.

2 Bar Harbor's tourism district meets Lewis and Adhikari's (2017, p. 501) definition of a neighborhood, which is "the housing and nearby land uses that serve them, primarily local businesses meeting routine needs, elementary schools, and small parks.".

3 The street address of Harbor Place is One West Street.

4 Acadia National Park visitor use statistics are from the National Park Service, U.S. Department of the Interior.

5 Taxable lodging sales data from Maine Revenue Services show that 25 percent of Bar Harbor's 2018 lodging sales took place in August, and July accounted for 23 percent of annual lodging sales.

6 This method of counting pedestrians and taking an average after walking in "both directions" is similar to the approach used by Jaakson (2004).

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[7] This method of scaling the number of pedestrians by the distance between the two points is different than the approach used by Jaakson (2004), who scaled the number of pedestrians by the amount of time spent walking. Our study accounts for the time spent walking between the two points, but uses walking speed (i.e., distance divided by time) as a second indicator of sidewalk congestion.

[8] Sidewalk width could also affect the number of pedestrians encountered in places with very dense congestion. The sidewalks in the area of study, however, were rarely at congestion levels where the sidewalk width would affect walking speeds or the number of people encountered. Fruin's (1971) seminal research on pedestrian LOS considered sidewalk width, but it used time-lapse photographs of very short and fixed sidewalk segments over which width and other characteristics could be readily measured and even adjusted. The approach used by Jaakson (2004) and in this study covered large areas of sidewalks (e.g., entire neighborhoods), where it would be impractical to measure sidewalk characteristics such as width, which can vary due to the placement of utility poles, vegetation, and accumulated snow.

[9] The percentage of observations collected on treacherous sidewalks and in the rain and snow is 4.8 percent, 1.9 percent, and 0.3 percent, respectively.

[10] This adjustment, which did not affect the results very much (see note 15), involved multiplying the count of pedestrians per 100 feet by the ratio of the actual walking speed when collecting the observation divided by 4.88 feet per second.

[11] The percentage of observations from each time period of the day are: 7 a.m. to 10 a.m. (33.6 percent), 10 a.m. to 1 p.m. (32.3 percent), 1 p.m. to 4 p.m. (16.1 percent), 4 p.m. to 7p.m. (10.1 percent), and 7 p.m. to 10 p.m. (7.9 percent).

[12] The percentage of observations from each street are: Main Street (31.6 percent), Cottage Street (27.0 percent), West Street (11.3 percent), and other places in the tourism district (30.1 percent).

[13] For example, on a given day, one ship might depart at 3 p.m., a second ship might depart at 5 p.m. and a third ship might depart at 7 p.m.

[14] As a robustness check to the OLS results, we re-estimated model 3 using Poisson, negative binomial, and zero-inflated Poisson estimators. The dependent variable used in this analysis is the count of pedestrians encountered per 100 feet (adjusted to a walking speed of 4.88 feet per second), rounded to the nearest whole number. The results pertaining to the impacts of cruise passengers on sidewalk pedestrian traffic are qualitatively similar—that is, the three additional regression models show positive and statistically significant effects—although the magnitudes of passenger impacts are smaller using the Poisson, negative binomial, and zero-inflated Poisson estimators. For example, the marginal effect associated with 100 additional passengers using a zero-inflated Poisson model (with day-specific dummy variables and the other control variables used in model 3) is 0.047, which is smaller than the comparable OLS coefficient of 0.079 in model 3. The OLS results are the main findings used in the paper because rounding the dependent variable to the nearest whole number, a necessary step when using the other estimators, removes useful information about the number of pedestrians observed on the sidewalk. For example, 13 percent of the observations have counts of between zero and 0.49 pedestrians per 100 feet (see Figure 2) and these observations, when pedestrians were observed, are treated as zeroes in the Poisson, negative binomial, and zero-inflated Poisson regression models.

[15] As a second robustness check, we re-estimated the four models shown in Table 2 using a dependent variable (i.e., count of pedestrians per 100 feet) that is not adjusted to a uniform walking speed of 4.88 feet per second. The results from these additional regressions are very similar to those presented in Table 2. For example, the effect of cruise passengers on sidewalk congestion in model 3 (using the unadjusted dependent variable) is 0.085, compared to an estimated coefficient of 0.079 shown in Table 2.

[16] The town referred to this experiment as a "demonstration project.".

[17] These estimates are for an observation logged on Main Street between 1 and 4 in the afternoon of August 27, 2018.

[18] These results are based on the two-part method of estimating the relationship between walking speeds and congestion (shown as the bold downward-sloping line) and the effects of cruise passengers on sidewalk pedestrian traffic (shown as the dashed vertical lines).

[19] The percentage of the slowdown attributed to the ship would be lower on dates in early August or July (i.e., other times when the summertime cruise passenger cap is in effect) because, in general, these days tend to have higher

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levels of baseline congestion than those observed in late August. The overall level of congestion, however, would be higher on dates in early August or July.

[20] For example, Papachristos et al., (2011) examined patterns of neighborhood change over 15 years.

[21] For example, similar methods could examine the effects of sporting events on pedestrian traffic at different distances from the venue. In a related analysis, Stitzel and Rogers (2019) looked at the effects of the Oklahoma Thunder NBA franchise on establishment-level sales at different distances from the team's arena.

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How to cite this article: Gabe T. Measurement and analysis of neighborhood congestion: Evidence from sidewalk pedestrian traffic and walking speeds. *Growth and Change*. 2021;52:1633–1651. https://doi.org/10.1111/grow.12499

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