Quantifying the benefits of peak spreading as a sustainable solution to addressing traffic congestion within the Al Ain private school zone in Abu Dhabi, United Arab Emirates

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Abstract

Owing to the over-concentration of about 40 schools along an approximately 5km stretch of an urban street within the City of Al Ain, UAE, daily traffic experiences and motorists frustrations manifested in terms of intersection delay, travel time, queues, travel speed and emissions have reached intolerable levels. While varied efforts are being put in place to address the situation, the Department of Transport (DoT) embarked on a pilot study that involved staggering of the starting time of schools over a time interval of 30 minutes for two weeks. The main objective of the study was to examine the effect of peak spreading on minimizing roadway congestion and other externalities within the private school zone. The study was cross-sectional in nature and involved traffic data collection before the implementation of the staggered school starting times and during the scheme. This purpose of paper therefore summarizes the findings of the scheme in quantifiable attributes of intersection delays, link travel times and traffic volumes intensities; and also formed the basis for recommendations to further address traffic congestion within the private school zone.
Keywords: peak spreading, peak interval, average peak interval traffic intensity, average time period traffic intensity, peak spreading efficiency ratio, delay, travel time.

1 Introduction

During the morning and evening peak travel periods, the road transport networks within the Al Ain private school zone experience congestion as travel demands

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approach capacity. Owing to the over-concentration of about 36 schools along an approximately 5km stretch of an urban street within the City of Al Ain, UAE, daily traffic experiences and motorists frustrations manifested in terms of intersection delay, travel time, queues, travel speed and emissions have reached intolerable levels. The severity of these impacts not only depends on demand-capacity relationships but also the temporal distribution of demand across the day. Because of the constraints of road capacity, peak spreading which is reminiscent of flexi-hours is one of the demand management ways of accommodating increasing traffic volumes and is becoming common on urban roadways. While varied efforts are being put in place to address the situation, the Department of Transport (DoT) embarked on a peak spreading pilot study that involved staggering of the starting time of some schools over a time interval of 30 minutes for two weeks. The objective of the study was to examine the effectiveness of peak spreading on minimizing roadway congestion within the private school zone area of Al Ain.

2 Characteristics and evidence of peak spreading

The phenomenon of peak spreading describes a dynamic process whereby the pattern of traffic demand changes over time from one where there is heavy peaking, to one where the demand spreads out over a longer period of time (Bolland and Ashmore [1]). Typically this results in the peak period lengthening, either side of the highest peak flow. So the smaller the differential between average and peak flows the better. When the bulk of the peak flow is concentrated into a very short period of time (heavy peaking), capacity is often breached and congestion results (Cambridge Systematics Inc. [2]).

The pattern of demand during the peak period is of crucial importance within the field of transportation planning when estimating necessary levels of road capacity, and the associated costs to provide and maintain this capacity. Capacity needs to cater for the maximum level of demand estimated at a future date, and if forecasts are not sufficiently accurate then this can lead to an inefficient allocation of resources (provision of over or under capacity). Broadly speaking conventional planning indicates that capacity should be provided to meet levels of maximum demand, i.e. those that occur in the peak hour.

There are two identified mechanisms as to why the peak period lengthens over time, both of them a direct consequence of excessive congestion (Hounsell [3]). Active spreading occurs when the individual trip maker makes a conscious decision to travel at a different time, either earlier or later than the most congested period, so as to miss the worst of the rush hour. In this case, travelers trade off congestion and their preferred time of travel, moving out of the highest peak to reduce the duration of their journeys, while still potentially incurring an element of disutility by having to leave home earlier or arrive at work later compared to their preferred time. Passive spreading, on the other hand, does not involve the trip maker choosing to travel in a different time segment to their one of choice. This occurs where increased delays in a network, due to an increase in traffic demand without changes in the demand profile, cause longer journey times through the network, and hence the tail of the peak period is extended.

2.1 Peak spreading measures of effectiveness

The objective of the pilot study was to determine whether the peak spreading program was effective in reducing traffic congestion during the pilot study duration. There are several approaches that can be employed to measure the effectiveness of peak spreading approaches; however, the application of these methods depends upon the available data (Barnes [4]). In this study, an approach based on a functional relationship that includes a measurement from the traffic flow profile within the study area has been adopted.

The measures of effectiveness of peak spreading involved an analysis of the traffic demand profile at each data collection points before and during the pilot study to enable an estimate of a number of attributes. A typical flow profile diagram showing the relationship between the time period and the peak interval, and the relationship between the average traffic intensities for the time period and the peak interval is presented in figure 1.

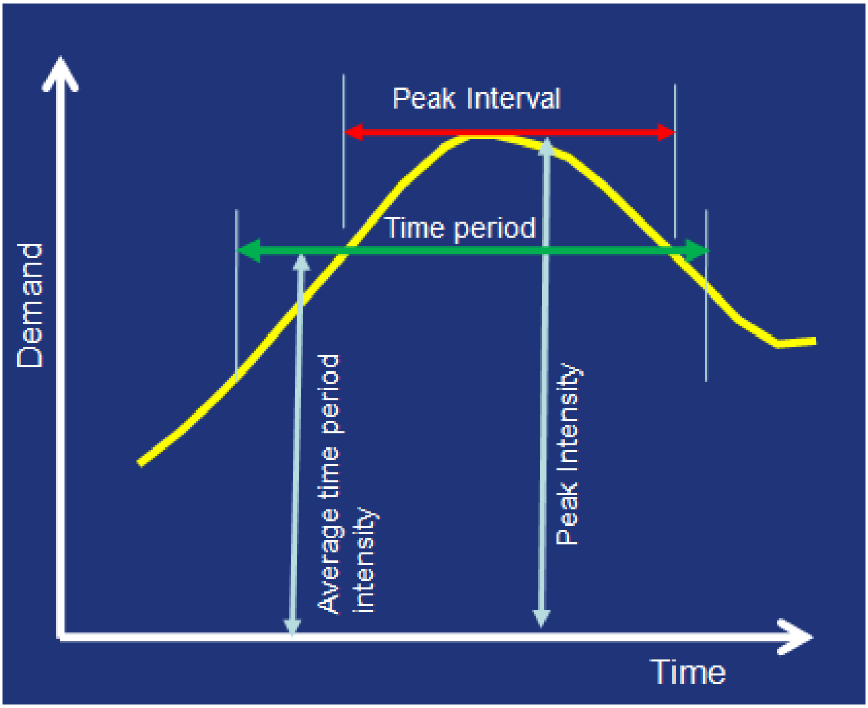

Figure 1: Travel flow profile.

As shown in Figure 1, the following peak spreading measures of effectiveness to be computed (Matsui and Fujita [5]).

1. Average time period traffic intensity
   The average time period traffic intensity is the average traffic flow for the time period under analysis. It is generally reported as vehicles per hour.
2. Peak interval
   The peak interval (in minutes) is that portion of the time period over which the demand is greater than the average time period traffic intensity.
3. Average peak interval traffic intensity
   The average peak interval traffic intensity is the average traffic flow for the peak interval.
4. Peak spreading efficiency ratio
   It is calculated as the ratio of total traffic at a particular location and the total maximum possible flow in a period. If the ratio is close to 100%, there is no spare capacity, when the rate of change is zero, no further peak spreading is possible.

Additionally, the collected data were analyzed using SIDRA INTERSECTION software to estimate the network parameters such as intersection delays and link travel time during AM and PM peak hours of flow. Questionnaires were also sent out to parents and teachers to get their feedback on the effectiveness of the peak spreading pilot scheme.

3 Demographics and travel behavior

With a population of about 600,000 inhabitants, the city exhibits one of the most highly motorized in the region with household car ownership estimated to be about 7 cars per household. The public transport mode share is very low and most of the trips are car-based. The city planning department had demarcated a zone for private schools (figure 2) development to cater for the needs of the expert population who constitute about 60% of the population. There are currently 36 schools with a student of about 39,694 students. This creates a uni-directional flow of traffic from other parts of the city to the school zone. As shown in figure 2, the results of the origin and destination survey of the school bound trips indicated that approximately 75% of the students travel from the central part of the city to the school zone.

4 The pilot study

The need for peak spreading and its feasibility was guided by the warrants presented in table 1 proposed by Allen and Schultz [6]. It was considered appropriate to consider peak spreading as the zone experiences prolonged durations of delay and inherently lacks an alternative route thereby meeting the requirements 3 and 4 of the warrants.

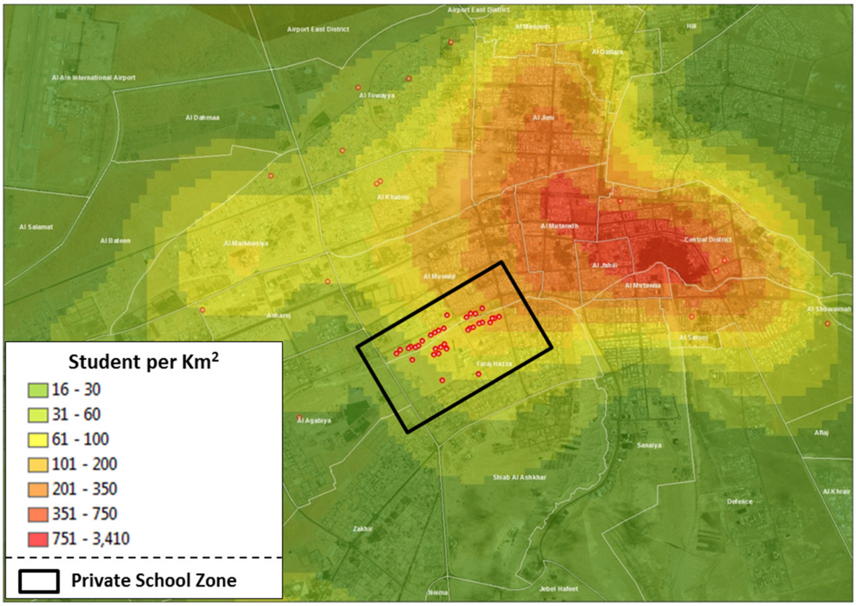

Figure 2: Demographics.

Table 1: Peak spreading warrants.

If the average minutes delay per delayed vehicle is…		and there is…	then peak spreading…
1	0–5		does not need to be considered
2	5–15	an alternative route	does not need to be considered
3	5–15	no alternative route	shall be considered
4	15 or greater		shall be considered

The pilot study was cross-sectional in nature and involved traffic data collection before and during the staggered program. Upon request, 19 schools with a student population of 21,100 students voluntarily agreed to delay their start times by 30 minutes where schools that normally start at 7:30AM agreed to begin their daily schedules at 8:00AM. The pilot study was conducted over a 2 week period during the month of March 2014. The survey comprised of intersection turning movement counts, link midblock volumes counts and speed measurements along the link. The traffic data collection points selected for the study captured all the access locations and intersections of the private school zone as shown in figure 3.

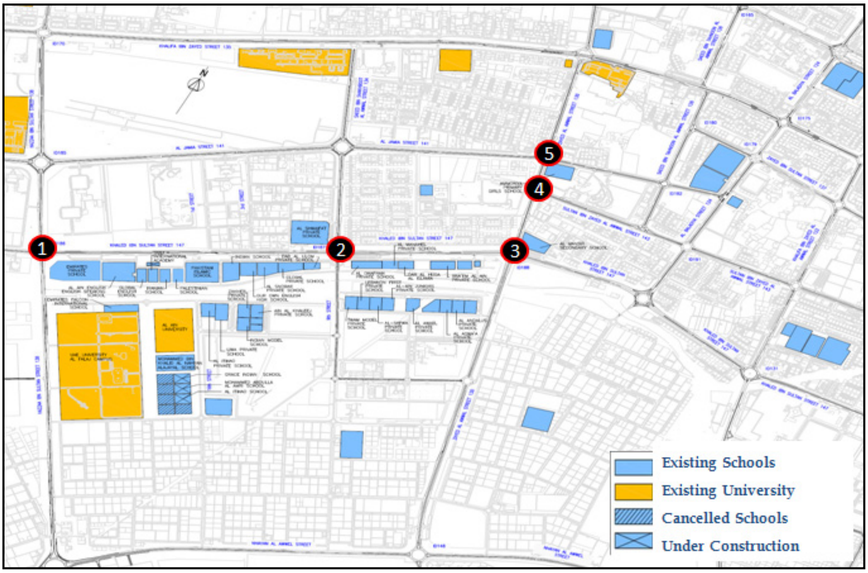

Figure 3: Al Ain private school zone road network and intersections.

4.1 Daily travel profile and mode choice

Figure 4 represents the typical travel demand profile traversing the school zone during an entire day. The AM peak is captured between 7.00am to 8.00am time period. However, the school travel demand for the PM peak period is captured between 2.00pm and 3.00pm, while the actual PM peak period of the link is

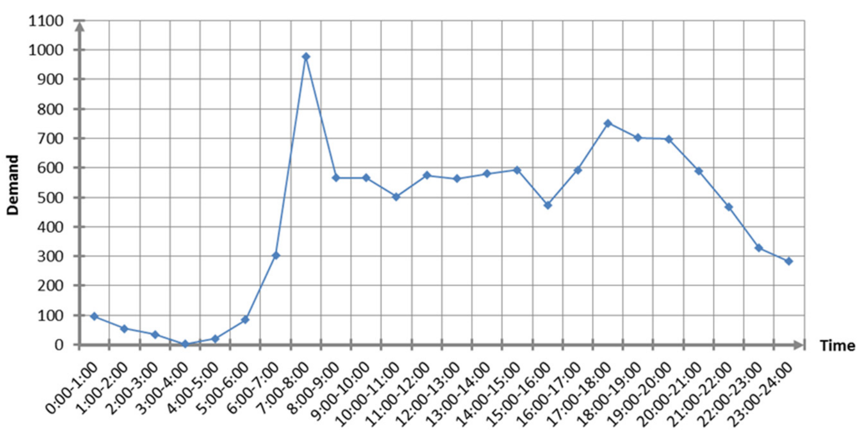

Figure 4: Travel demand profile.

between 6.00pm and 7.00pm. As expected, and as shown in figure 5, private motorized mode is by far the most dominant mode choice (92%) especially for all travels made to the school zone. Schools bus and the public bus contribute to a combined 6% of the travel demand.

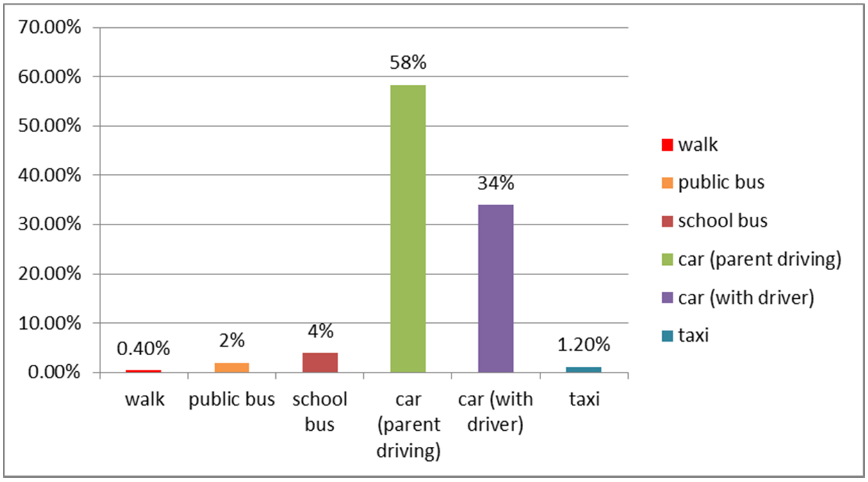

Figure 5: Mode share.

5 Results

The results of the peak spreading pilot scheme are presented in terms of the peak spreading measures of the effectiveness; road network performance measures and the feedback obtained from the questionnaires.

5.1 Peak spreading measures of effectiveness

A summary of the peak spreading measures of effectiveness results before and during the pilot scheme for a typical weekday is presented in table 2. The results show a reduction of average traffic intensity by 25% and 17% respectively during AM and PM peak hours of flow along the school zone main road corridor. Importantly, the study revealed the broadening of the peak interval by 12 minutes during the AM peak and 17 minutes during PM peak hour. Further, there was a marked reduction in the average peak interval traffic intensity by about 288vph and 354vph respectively representing 34% and 46% for the AM and PM peak hours of flow. Finally, there was a significant reduction in the peak Spreading Efficiency Ratio of 22% and 30% respectively for the AM and PM peaks during the pilot scheme. This indicates that there was an increase in spare capacity along Khaled bin Sultan Street resulting from the peak spreading. A corresponding change in the travel flow profile for the before and during the peak spreading pilot scheme is presented in figure 6.

Table 2: Results of peak spreading measures of effectiveness.

Measures of effectiveness	Before Peak Spreading		During Peak Spreading		Percentage Change	
	AM Peak	PM Peak	AM Peak	PM Peak	AM Peak	PM Peak
Average time period traffic intensity	987vph	624vph	742vph	532vph	25%	15%
Peak interval	32mins	22mins	44mins	39mins	27%	44%
Average peak interval traffic intensity	1122vph	689vph	742vph	442vph	34%	46%
Peak Spreading Efficiency Ratio	98%	77%	76%	54%	22%	30%

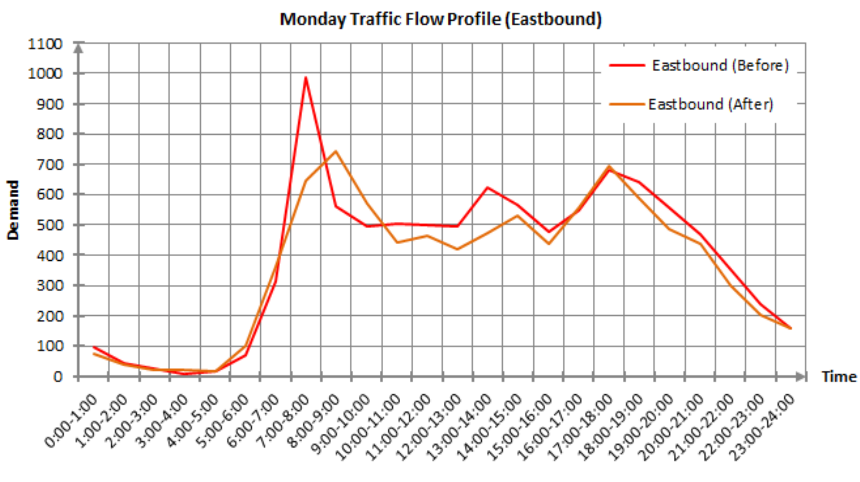

Figure 6: Mode share.

5.2 Road network performance measures

The intersection capacity performance analysis was undertaken with the aid SIDRA intersection software and the results generally indicated a reduction in delays at the studied critical roundabouts intersections. As presented in table 3, whereas the overall intersection level of service (LOS) remained F for all the intersections during AM peak hour, the percentage reduction of delays during the pilot scheme was significant. Similarly there was a significant reduction in intersection delays during the pilot scheme for the PM peak. Comparatively, the PM peak hour reductions in delay are more pronounced than the AM peak as many parents only drop their children to school in the morning and allow them to be driven by school buses in the afternoon which effectively reduces peak hour travel intensity.

Table 3: Delay and LOS.

Node	Before Peak Spreading				During Peak Spreading				% Change in Delay	
	AM Peak		PM Peak		AM Peak		PM Peak		AM Peak	PM Peak
	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS		
1	356	F	156	F	242	F	92	F	32%	41%
2	324	F	134	F	232	F	78	F	28%	42%
3	318	F	97	F	218	F	59	F	31%	39%
4	246	F	124	F	162	F	84	E	34%	32%
5	287	F	136	F	183	F	79	F	36%	42%

The link travel times ware also determined before and during the peak spreading program as a function of the average speed and the link length. As shown in table 4, link 1–2 had the longest journey time during the AM peak hour before the pilot scheme; however, it also showed a remarkable percentage (18%) reduction in journey time during the pilot program. Similarly other links also showed a reduction in travel time during the AM peak hour by varied percentages. The reduction of travel time was more pronounced during the PM peak than the AM peak potentially attributed to that fact that the PM traffic intensities were lower than the AM peak. On average there was a travel time reduction of 15% and 28% respectively within the school zone network as a result of implementing the peak spreading pilot scheme.

Table 4: Link travel times.

Link	Before Peak Spreading		During Peak Spreading		% Change in Travel Time	
	AM Peak (minutes)	PM Peak (minutes)	AM Peak (minutes)	PM Peak (minutes)	AM Peak	PM Peak
1–2	15.2	10.6	12.4	8.2	18%	23%
2–1	7.4	5.4	5.9	3.6	20%	33%
2–3	6.2	5.1	4.8	3.7	18%	29%
3–2	5.3	4.2	4.4	3.1	17%	26%
3–4	5.1	4.2	4.3	2.8	16%	33%
4–3	4.2	3.3	3.7	2.1	12%	36%
4–5	3.6	3.1	3.2	1.9	11%	39%
5–4	2.4	1.4	2.2	1.3	8%	7%

5.3 Questionnaire feedback

Questionnaires were sent out to schools and parents in order to gauge their feedback regarding the effectiveness of the pilot scheme under the auspices of the timing, commitment and duration of the pilot scheme, and whether there were perceived benefits. While all the schools were aware of the pilot scheme, there was no complete adherence to the program. As presented in table 5, there was an overall positive feedback (91%) towards the program with many schools indicating that they had noticed reduced congestion. The timing and duration were also favorable to many schools and parents. However, there were concerns raised with regards to making the program mandatory, staggering the school finishing times and increasing the extent of the stagger duration.

Table 5: Feedback.

Question	Schools interviewed	Suitable	Not suitable	Percent of suitable	Percent of non-suitable
Pilot scheme timing	33	33	0	100%	0%
Pilot scheme timing commitment from parents	33	29	4	88%	12%
Pilot scheme duration	33	31	2	94%	6%
Did the school benefit from the pilot scheme	33	29	4	88%	12%
Did students, teachers, parents etc. understand the pilot scheme?	33	30	3	91%	9%
Overall feedback	33	30	3	91%	9%

6 Discussion

This study has demonstrated the effects of staggered school start times on the road network performance and the key peak spreading measures of effectiveness. Various variants of variable (staggered, flexi and compressed) work hours program have been employed by many cities dating back to the early 70s as to manage travel demand with considerable transportation, socio-economic and sustainability benefits.

Early studies showed varied changes in the distribution of demand by motorists resulting from variable work programs. A 1975 study in Ottawa Canada showed that the change in the morning travel demand was minimal with the peak 15 minutes occurring a quarter of an hour earlier with a slightly flatter distribution. In the evening the difference was more noticeable, as the peak began half an hour earlier and was considerably flatter, with approximately 20% less traffic on the roads at the most congested point in evening peak (Safavian and McLean [7]). Similarly, in Manhattan, there was a substantial and continuing reduction in congestion [in terms of passengers using public transport] of 6 per cent in the peak 15 minutes was observed at three of the busiest Transit authority subway stations (O'Malley and Selinger [8]). The number of passengers had decreased by 26% in the peak 15 minute period (09:00 to 09:15) and increased by 24% between 08:30 and 08:45. Evening peak travel was monitored at a different station and revealed a reduction in passenger numbers of 18% between 17:00 and 17:15, and an increase of 53% between 16:30 and 16:45, when additional train capacity was also available.

In Singapore, Moraillon and Brick [9] monitored flexible working practices for over an 18 month period for 12 participating organizations and the results from the surveys demonstrated a positive impact on travel time with an overall reduction of 9–12% in peak hour trips recorded. During the preparations for the 2012 London Olympics, Transport for London established the Travel Advice for Business (TAB) program where areas of high travel demand were identified, with employers within them encouraged to re-time journeys to travel earlier or later to avoid busy periods. On average, over all the offices included in the study, peak arrivals as a percentage of all trips generated decreased by 11 per cent in the first weeks of flexible working hours. The morning peak 15 minutes also shifted from 08:00–08:15 to 07:45–08:00 (Vanson [10]). The ability of flexible hours to spread demand was reflected by the keenness of staff to start and finish early in a bid to avoid congestion. This ensured that spare capacity on the network resulted in smooth access to and between Olympic venues.

Consistent with this study, Holyoak and Taylor [11] characterized peak spreading as having two discrete dimensions. One dimension is measured as the proportion of change in traffic intensity that occurs during the peak hour while the other dimension is the change in the length of the peak period itself. In a study by Miller [12] aimed at determining the change in the K-factor (defined as the proportion of the 24-hour traffic volume that occurs during the peak hour) in Northern Virginia USA, the results showed that the average annual K-factor decreased by an average of 0.006 and the 24-hour volume-to-capacity ratio, also increased by an average of 0.7. The study also found a strong relationship between the peak-spreading, speed differences and vehicle emissions.

The demand impacts resulting from flexible working hours depend on the up-take of the option by employees and whether it is used as an opportunity to use alternatives to private car use. A study by Picado [13] found out that whereas two-thirds of employees surveyed have flexible work schedules, less than twenty percent of them actually shift their commute times to avoid congestion. This outcome is almost reminiscent of the present study as some parents still opted to travel during the normal peaks as they trip chain by dropping their kids to school and then to work. This could be because fitting in with other duties does not allow journeys outside of peak hours and the need to meet these responsibilities necessitate routine travel (Anis [14]).

While this study has demonstrated the evidence of peak spreading, Gordon *et al*. [15] in their study concluded that there is little evidence of peak spreading in major urban areas as the spatial structure measured in terms of other factors such as the density, urban size, and decentralization, etc. plays a key role in the peaking of congestion. While these factors affect the travel time, they may consequently play a role in the peak-hour congestion.

From a policy perspective and the evident benefits, many cities around the world are resorting to variable working programs as a sustainable travel demand management measurer. However, for these programs to be much beneficial, instruments related to concentration of occupations suitable for flexible working hours around public transport hubs with links to key residential areas; passive advertising campaigns; provision of HOV lanes to increase public transport service levels; urban road charging and real time driver information should be reinforced to overcome any barriers to flexible work programs.

7 Conclusions and recommendations

This study was undertaken in order to quantify the benefits of peak spreading as an alternative soft measure in minimizing the traffic congestion within the private school zone. On the basis of the analytical results and observations, the following conclusions can be drawn:

1. There was an effective reduction in delays along Khaled bin Sultan Street as a result of staggering intervals.
2. While the results depict a reduction in the average peak period traffic intensity in the ranges of 10–12%, the peak spreading efficiency ratio remained high, depicting a lack of spare capacity along the main corridor.
3. There was a general appreciation of the benefits associated with the peak spreading pilot scheme from the schools and parents. As such efforts are in place to

In order to improve the traffic situation within the school zone, a number of recommendations have also been put forward:

1. Discussions are underway with the schools to lengthen the duration of staggering to one hour
2. School relocation strategy that will involve shifting of some schools to already identified locations within the city so as to spread traffic during the peak hours of flow.
3. A moratorium has been enforced to inhibit the expansion of schools or constructing of new ones within the zone.
4. Implementation of transport mobility management proposals that advocate for more public transport use to the private school zone and mandatory school bus program.
5. Other roadway improvements measures involving the conversion of the roundabouts to signalized intersections.

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