Peak Spreading Models

Presented by

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Outline

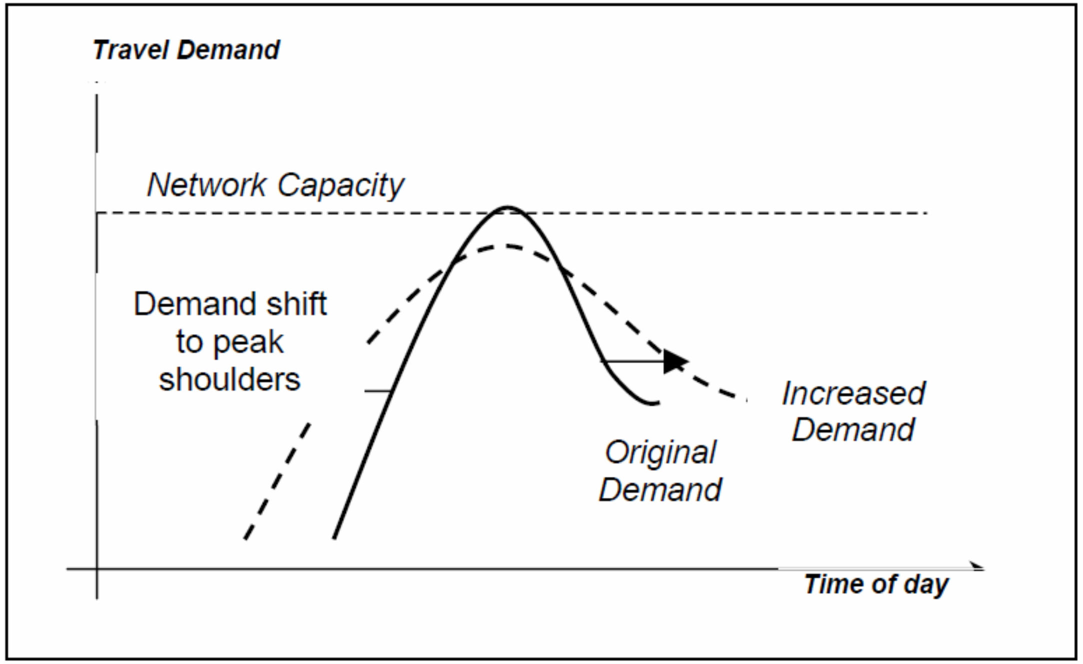
- Introduction: Definition and elements
- Literature review: Peak spreading model approaches and their limitations
- Example model
- Importance of peak spreading in transportation
- Conclusion

Introduction : Peak spreading

- "A dynamic process whereby the pattern of demand changes over time from one where there is heavy peaking to one where the demand spreads out over a longer period."

Bolland and Ashmore (2002)

- Peak spreading essentially results in a travel demand shift from a critical peak time to the peak shoulders
- Average daily peak period traffic becomes wider and flatter.



Introduction : Elements of Peak spreading

1. Active peak spreading:
    - Occurs when the individual traveler makes a conscious decision to retime the start of their journey in order to avoid traffic congestion and delays during the most heavily congested part of the peak.
    - More prevalent in morning peak period (The UK DMRB, 2005)

2. Passive peak spreading
    - Occurs when travelers during the peak experience delays to their trip due to congested traffic conditions. These delays lengthen the individual travel time and therefore prolong the peak period to the post-peak shoulder.
    - No change in travel demand
    - More prevalent in evening peak period (The UK DMRB, 2005)

Hounsell (1991)

In practice they both occur simultaneously to some degree

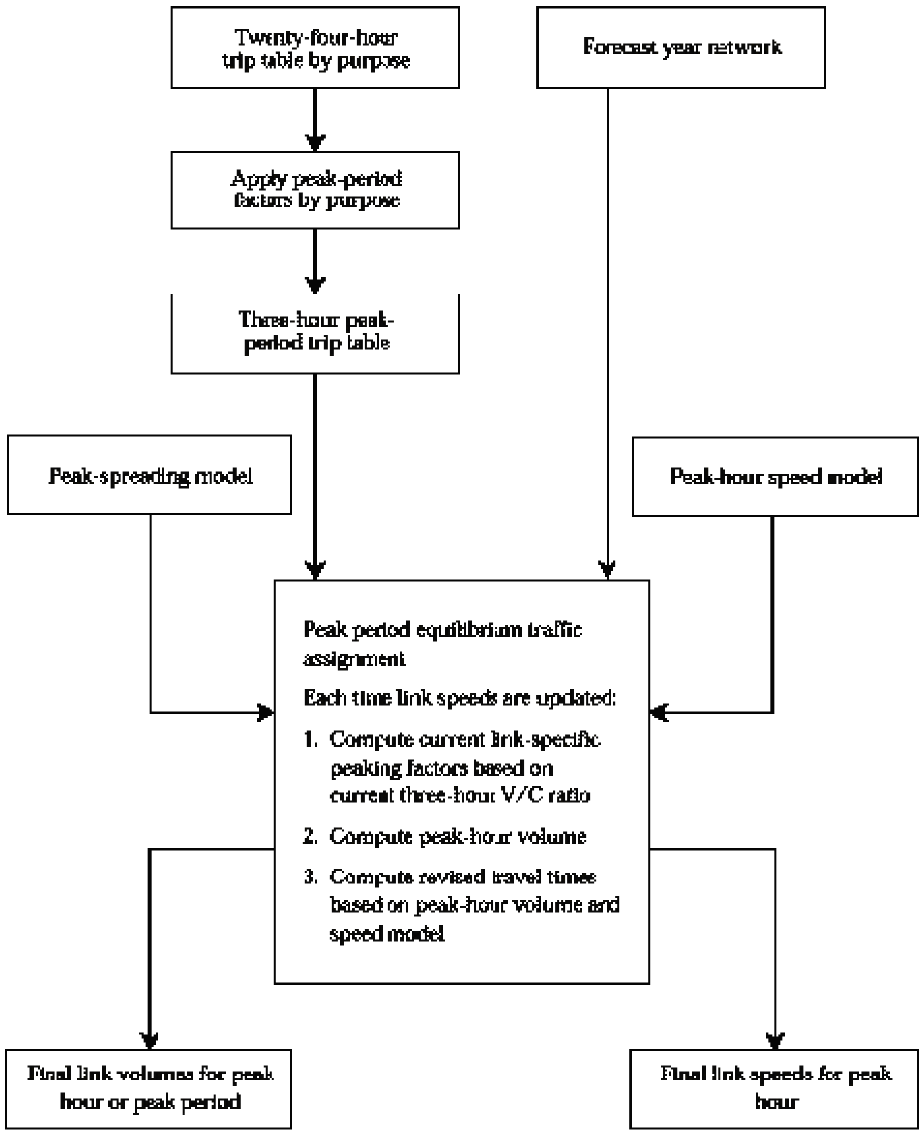
Literature review: Approaches for peak spreading models

- Link-based peak spreading models
- Trip-based peak spreading models
- System-wide peak spreading models

(TRAC-1991)

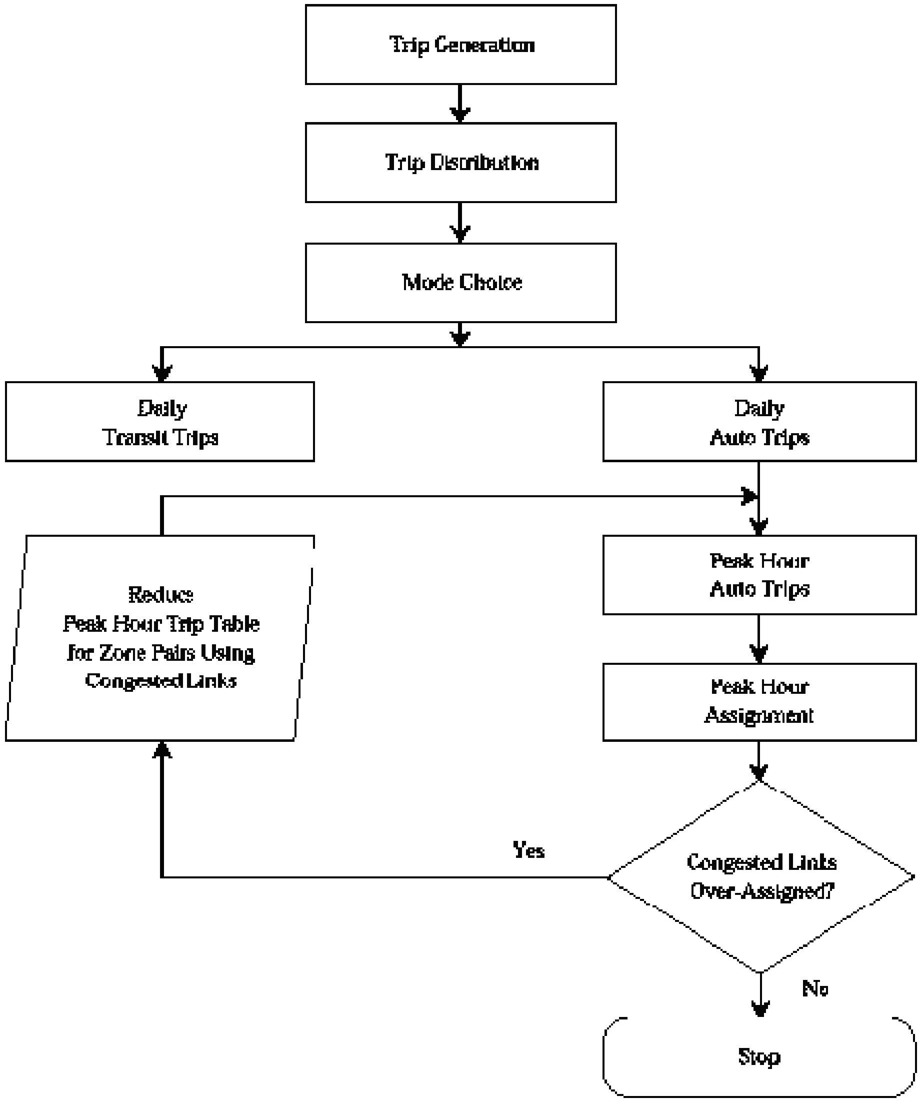
Literature review:
Link-based peak spreading models

- Obtain more realistic traffic assignments.
- Assumption-all the trips would occur in the three/four-hour period under consideration
- Application
  - Phoenix area, Connecticut area
- Advantage:
  - Provides an estimate of the net effect of traffic congestion
  - Produces reasonably accurate solution for stable system
- Limitations-
  - No guarantee of continuity of flow in the peak hour prediction.
  - Does not reflect spreading of the peak outside of a three-hour period.
  - Does not identify the magnitude of behavioral response



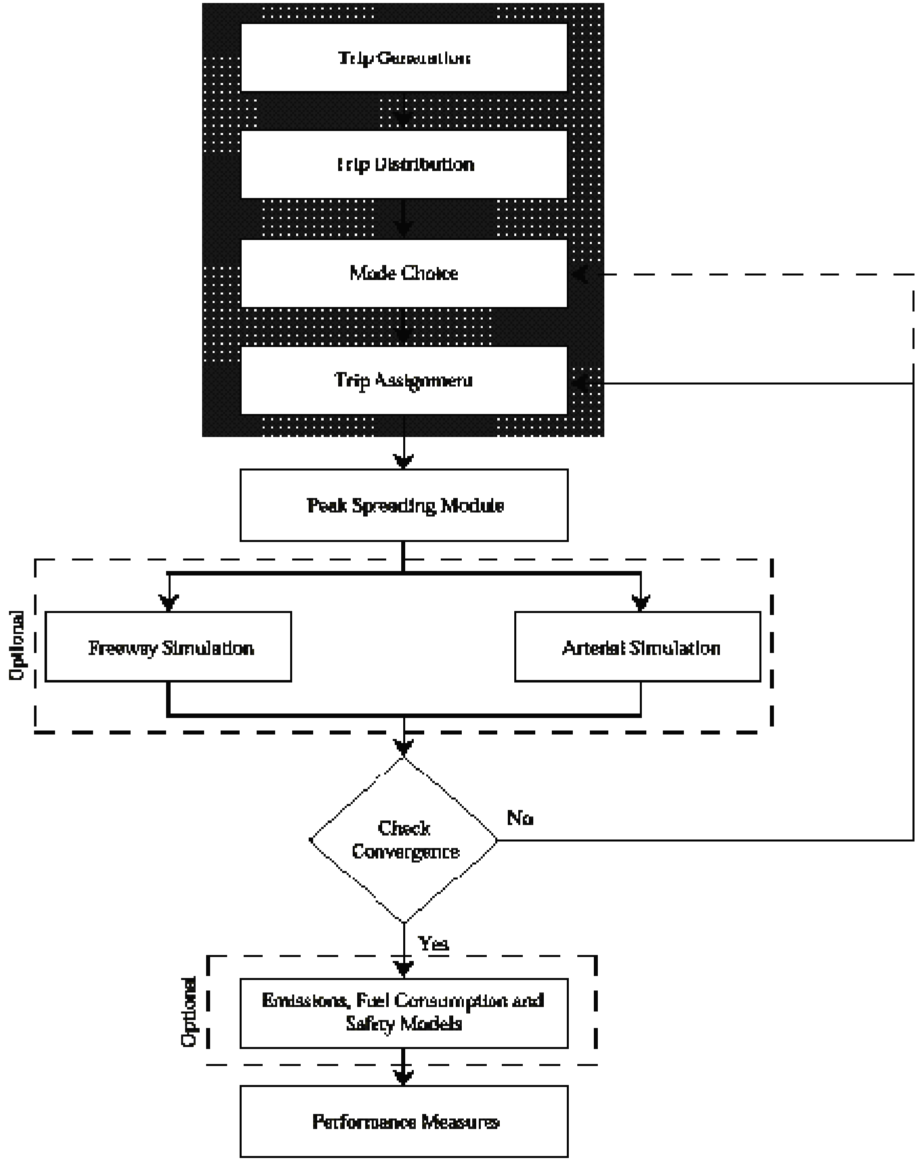
Literature review:
Trip-based peak spreading models

- Spreads the number of trips for an origin-destination interchange that occur in the peak period or peak hour.
- Application:
  - Tri-Valley Model Peak Spreading-San Francisco Bay Area
  - Peak Spreading in the Central Artery/Tunnel Project-Boston, Massachusetts
  - Washington D.C. Peak Spreading Model
- Advantage:
  - Selective reduction over global reduction
- Limitations
  - No explicit treatment of the trips being reduced
  - It is assumed that these trips cannot be completed in the peak hour and, thus, have been forced to travel outside of the peak hour
  - Assumes constant three hour peak period



Literature review:
System-wide peak spreading models

- Considers the system-wide excess travel demand and delay and distributes excess travel demand between the individual travel hours that comprise the peak period
- Application:
  - I-880 corridor in Alameda County, California.
- Advantage
  - Incorporates ITS technologies
  - Models temporal responses as system wide measure
- Limitation:
  - It is not sensitive to different trip purposes
  - It is not sensitive to traffic congestion on specific links or specific origin-destination flows.



Literature review: Peak Spreading sub-models

- Incorporates land-use and network characteristic (Replogle, 1990)
- Includes independent variable beyond consgestion (Dulles corridor study, Allen and Schultz, 1996)
- Considers finite number of alternatives (Ramsey, 1995)
- Etc.

Example Model

Regional and area-type modeling of peak spreading on Connecticut freeways

John N. Ivan and Scott A. Allaire, 2001

Data and Assumptions

- Hourly traffic volume for 5 year period
- 10 Freeway links in Connecticut
- Selected stations have v/c ratio > 0.5
- Peak period 3:00-7:00 pm (4-h)

Methodology

- Functional form of peak spreading period,

$$P = \frac{1}{4} + ae^{bx}$$

Where, $P = ratio\ of\ peak\ hr\ volume\ to\ 4 - h\ peak\ period\ volume\ or\ peaking\ factor$

$x = v/c$ *ratio for the 4-h peak period*

$a =$ scale coefficient

$\mathrm{b} =$ slope coefficient

(borrowed from Louden, 1988)

- By transforming,

$$\ln\left(P - \frac{1}{4}\right) = \ln a + bx$$

$$y = C + bx$$

Where, $\mathrm{y} = \ln\left(P - \frac{1}{4}\right)$

$\mathrm{C} = \ln(a)$

Methodology

- The congestion measure, or v/c ratio, of the link is most likely the best variable for capturing the peak-spreading phenomenon. But its affect varies from link to link, according to trip and trip-maker characteristics (Allen and Schultz 1996).
- Hypothesis:
- Much of this variation can be explained by the location of the link.
- So models were estimated with two
  - Regional model- by region within the state (4 regions)
  - Area type model- by location with respect to the region in which the link is located.

Regional model

Capitol (CP)	Southeast (CE)	Southwest (W)	NY Metro (NY)
Wethersfield	East Lyme	Newtown	Norwalk
Manchester	Groton	Middlebury	
West Hartford		Branford	
Enfield			

$$y = C_o + C_R D_R + C_{CP} D_{CP} + C_{SE} D_{SE} + C_{SW} D_{SW} + b_o X + b_R X_R + b_{CP} X_{CP} + b_{SE} X_{SE} + b_{SW} X_{SW}$$

D= Dummy variable

X= v/c ratio

$\mathrm{C} = \ln(a)$

a = scale coefficient

b = slope coefficient

Regional model (modified)

Capitol (CP)	Southeast (CE)	West (W)	Shoreline (SL)	NY Metro (NY)
Wethersfield	East Lyme	Newtown	Branford	Norwalk
Manchester	Groton	Middlebury		
West Hartford				
Enfield				

$$y = C_o + C_R D_R + C_{CP} D_{CP} + C_{SE} D_{SE} + C_W D_W + C_{SL} D_{SL} + b_o X + b_R X_R + b_{CP} X_{CP} + b_{SE} X_{SE} + b_W X_W + b_{SL} X_{SL}$$

Area type model

Area Type Categorization of Study Locations

Group number	Area type	Locations	Statistics on X Minimum	Maximum	Mean
1	Urban	W. Hartford	0.50	0.90	0.7231
		Wethersfield			
2	Suburban	Enfield	0.50	0.81	0.5870
		Middlebury			
3	Ex-urban	Newtown	0.50	0.94	0.6408
		Groton			
		Manchester			
		East Lyme			
4	Shoreline	Branford	0.50	0.84	0.6617
5	NYC Metro	Norwalk	0.50	0.82	0.7020

$$y = C_o + C_R D_R + C_1 D_1 + C_2 D_2 + C_3 D_3 + C_4 D_4 + b_o X + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4$$

**Group 5 was chosen as base group (consisted with the regional model)

Model application: Complete model

- Selected model-Modified area type
- New model- including variable for reverse commute direction

$$y = C_o + C_R D_R + C_{CP} D_{CP} + C_{SE} D_{SE} + C_W D_W + C_{SL} D_{SL} + C_{R-CP} D_{R-CP} + C_{R-SE} D_{R-SE} + C_{R-w} D_{R-W} + C_{R-SL} D_{R-SL}$$

$$+ b_o X + b_R X_R + b_{CP} X_{CP} + b_{SE} X_{SE} + b_W X_W + b_{SL} X_{SL} + + b_{R-CP} X_{R-CP} + b_{R-SE} X_{R-SE} + b_{R-W} X_{R-W} + b_{R-SL} X_{R-SL}$$

TABLE 13. Regression Results: Complete Model

	Complete Model (Separate Direction Variables for Each Region)		Complete Model with Non-Significant Variables Removed	
	Coefficient	t-statistics	Coefficient	t-statistics
(a) Constants				
C_0	1.205	7.243	1.205	7.231
C_{CP}	−3.656	−21.218	−3.656	−21.183
C_{SE}	−4.244	−23.669	−4.285	−23.870
C_W	−3.595	−18.957	−3.578	−18.989
C_{SL}	−1.691	−7.819	−1.691	−7.806
C_R	−2.895	−12.271	−2.895	−12.251
$C_{R\text{-}CP}$	−1.233	−6.975	−1.233	−6.964
$C_{R\text{-}SE}$	−3.265	**−1.064**	—	—
$C_{R\text{-}W}$	−0.776	−2.422	−1.003	−43.192
$C_{R\text{-}SL}$	−2.351	−11.127	−2.351	−11.108
(b) Slopes				
b_0	−7.639	−32.321	−7.639	−32.268
b_{CP}	6.618	26.992	6.618	26.947
b_{SE}	7.178	27.640	7.236	27.835
b_W	6.015	21.366	5.987	21.452
b_{SL}	2.794	8.870	2.794	8.855
b_R	3.737	9.860	3.737	9.844
$b_{R\text{-}CP}$	0.801	2.508	0.801	2.504
$b_{R\text{-}SE}$	4.489	**0.780**	—	—
$b_{R\text{-}W}$	−0.410	**−0.710**	—	—
$b_{R\text{-}SL}$	3.103	8.975	3.103	8.960
(c) Statistics				
R-squared	0.487		0.486	
SSR	2,303.582		2,295.078	
SSE	2,422.278		2,430.782	
F-statistic	744.482		877.904	
DOF	14,874		14,877	

Insignificant

Final regional model results

Model application: Complete model

- From the table- for Capitol region:

$$C = C_o + C_{CP} = 1.205 - 3.656 = -2.451$$
$$b = b_o + b_{CP} = -7.639 + 6.618 - 1.021$$

- From the functional form of peak spreading model:

$$\ln\left(P - \frac{1}{4}\right) = C + bX = -2.451 - 1.021X$$

- For the reverse commute direction:

$$\ln\left(P - \frac{1}{4}\right) = -2.451 - 1.021X - 1.233D_R + 0.801X_R$$

Where,

$$D_R = \begin{cases} 1 & \textit{If flow is in the reverse commute direction} \\ 0 & \textit{otherwise} \end{cases}$$

$$X_R = \begin{cases} X & \textit{If flow is in the reverse commute direction} \\ 0 & \textit{otherwise} \end{cases}$$

	Complete Model with Non-Significant Variables Removed	
	Coefficient	t-statistics
C_0	1.205	7.231
C_{CP}	−3.656	−21.183
C_{SE}	−4.285	−23.870
C_W	−3.578	−18.989
C_{SL}	−1.691	−7.806
C_R	−2.895	−12.251
$C_{R\text{-}CP}$	−1.233	−6.964
$C_{R\text{-}SE}$	—	—
$C_{R\text{-}W}$	−1.003	−43.192
$C_{R\text{-}SL}$	−2.351	−11.108
b_0	−7.639	−32.268
b_{CP}	6.618	26.947
b_{SE}	7.236	27.835
b_W	5.987	21.452
b_{SL}	2.794	8.855
b_R	3.737	9.844
$b_{R\text{-}CP}$	0.801	2.504
$b_{R\text{-}SE}$	—	—
$b_{R\text{-}W}$	—	—
$b_{R\text{-}SL}$	3.103	8.960

Commute and Reverse-Commute Direction Model

		Commute Direction		Reverse-Commute Direction	
Region	Sites	a	b	a	b
NYC Metro	Norwalk	3.3368	−7.639	0.1845	−3.902
Shoreline	Branford	0.6151	−4.845	0.0586	−1.742
West	Newtown Middlebury	0.0932	−1.652	0.0342	−1.652
Capitol	W. Hartford Wethersfield Manchester Enfield	0.0862	−1.021	0.0251	−0.220
Southeast	East Lyme Groton	0.0460	−0.403	0.0460	−0.403

Prediction of Peak-Hour Volume from Aggregate Peak-Period Volume

Site	*AWDT*	*PPV*	*PPV/C*	Estimated *a*	Estimated *b*	Estimated *P*	Predicted *PHV*	Observed *PHV*	Percent difference
I-91 North, Wethersfield	56,717	15,944	0.45	0.0251	−0.220	0.273	4,348	4,546	4.3
I-91 South, Wethersfield	55,241	17,610	0.67	0.0862	−1.021	0.293	5,168	5,256	1.7
I-84 East, Newtown	31,299	10,888	0.62	0.0932	−1.652	0.283	3,086	3,177	2.9
I-84 West, Newtown	31,268	7,963	0.45	0.0342	−1.652	0.266	2,120	2,174	2.5
I-84 East, Manchester	45,418	17,578	0.66	0.0862	−1.021	0.294	5,167	5,203	0.7
I-84 West, Manchester	45,667	10,662	0.40	0.0251	−0.220	0.273	2,911	2,838	2.6
I-95 North, Norwalk	59,934	18,223	0.69	3.3368	−7.639	0.267	4,868	4,917	1.0
I-95 South, Norwalk	34,159	13,988	0.53	0.1845	−3.902	0.273	3,823	3,829	0.1
I-95 North, Branford	35,382	11,241	0.65	0.6151	−4.845	0.276	3,107	3,124	0.6
I-95 South, Branford	34,893	9,163	0.53	0.0586	−1.742	0.273	2,504	2,521	0.7
I-95 North, East Lyme	27,520	7,477	0.43	0.0460	−0.403	0.289	2,158	2,132	1.2
I-95 South, East Lyme	27,247	7,895	0.45	0.0460	−0.403	0.288	2,277	2,225	2.3
I-95 North, Groton	32,181	10,949	0.62	0.0460	−0.403	0.286	3,130	3,238	3.3
I-95 South, Groton	30,321	7,475	0.28	0.0460	−0.403	0.291	2,176	2,065	5.4
I-84 East, W. Hartford	54,932	13,657	0.52	0.0251	−0.220	0.272	3,720	3,778	1.5
I-84 West, W. Hartford	56,502	20,101	0.76	0.0862	−1.021	0.290	5,823	5,781	0.7
I-91 North, Enfield	39,662	15,234	0.58	0.0862	−1.021	0.298	4,535	4,491	1.0
I-91 South, Enfield	40,496	9,859	0.38	0.0251	−0.220	0.273	2,692	2,685	0.3
I-84 East, Middlebury	26,755	8,944	0.52	0.0932	−1.652	0.289	2,589	2,555	1.3
I-84 West, Middlebury	27,091	7,019	0.41	0.0342	−1.652	0.267	1,877	1,941	3.3

Importance of peak spreading in transportation

- Impact on capital construction investment
  - Failure to take this into account can result in overestimation of traffic in peak period and underestimation of traffic volumes in the shoulders of the peak
  - Improvement in capacity-> retiming of remand to peak period- “reverse peak spreading” (Johnston, 1991)

- Impact on air quality analysis for conformity requirements
  - Higher emissions for vehicle at low and high end of speed
  - Peak period volumes must be taken into account separately

- Impact on transportation demand management investments
  - Different TDM strategies might be required to handle demand (active peak spreading)
  - Before implementing policies, modeling is required

Conclusion

- Modeling peak spreading is essential for to enhancing the existing traditional four-step transportation planning procedure
- Active and passive peak spreading should be taken into account separately
- Appropriate model should be considered for appropriate scenarios
- Demand forecasting and demand management strategies should be considered to account for peak spreading in long term investment

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