APPENDIX 2

Related Memos

CTPS

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CENTRAL
TRANSPORTATION
PLANNING
STAFF

MEMORANDUM

TO: Route 2 Crosby's Corner Files **June 26, 1992**

FROM: Linda Pehlke LP

RE: Analysis of Crosby's Corner Fly-Over Design Alternative

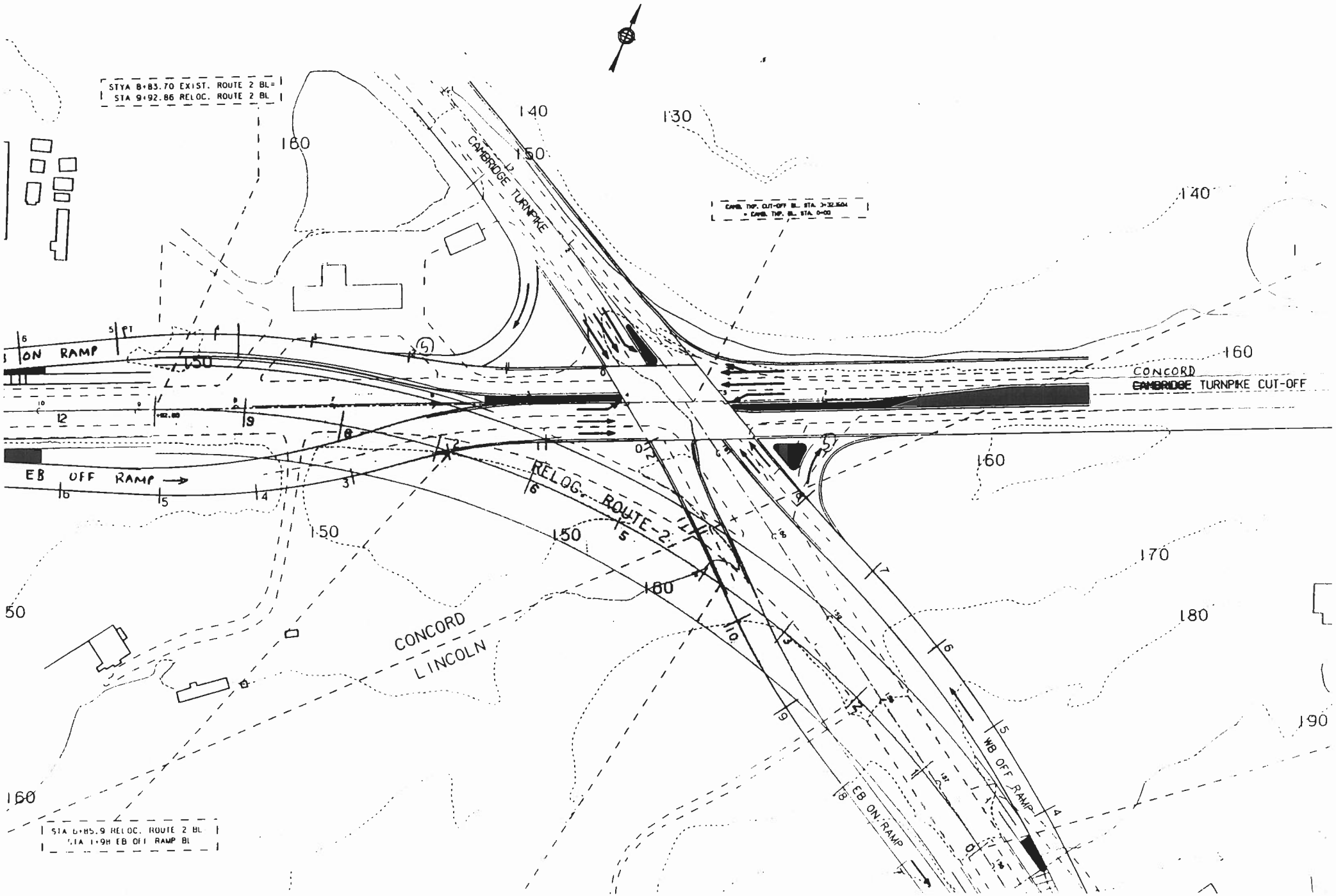
This memo will describe the assumptions and methodologies used to assess the 1995 operational viability of a proposed fly-over design alternative at Route 2 and the Cambridge Turnpike (Route 2A), otherwise known as Crosby's Corner.

Travel Demand Modeling

The Route 2 network used for this analysis was developed by CTPS as part of the Route 2 Corridor Study and the Hanscom Air Force Base Employee Relocation Traffic Impact Study. The travel demand forecasting program developed at CTPS known as "The Highway Emulator" was used. The base year network was calibrated to 1990 traffic counts. 1995 traffic volumes were forecast based on a most likely socioeconomic growth scenario For a more detailed description of the modeling process, base year traffic counts and intersection analyses see the MIT Lincoln Laboratory Employee Relocation Traffic Impact Study dated April 1992, by CTPS.

Build-Year Analysis

1995 traffic volume forecasts, originally developed for the Hanscom Air Force Base study were used to simulate "build-year" volumes for the fly-over analysis. Build-year conditions were assessed in terms of intersection level of service for the remaining "ground level" intersection, and ramp analyses were performed for the on and off ramps of the fly-over in both the AM and PM peak hours. The preliminary design for the intersection as evaluated is attached. The results of the build year analyses are presented below. The actual computer printouts of the intersection and ramp analyses are also attached to this memo.


STYA 8+83.70 EXIST. ROUTE 2 BL=
STA 9+92.86 RELOC. ROUTE 2 BL
CAMBRIDGE TURNPIKE
CAMB. TNP. CUT-OFF BL. STA. 3+32.50
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ON RAMP
EB OFF RAMP
RELOC. ROUTE 2
CONCORD
CAMBRIDGE TURNPIKE CUT-OFF
CONCORD
LINCOLN
WB OFF RAMP
EB ON RAMP
STA 6+85.9 RELOC. ROUTE 2 BL
STA 1+98 EB OFF RAMP BL

1995 Intersection Level of Service Analysis

As reconfigured, the remaining at-grade intersection is a four way signalized intersection, with the east and south approaches being the termini of the on-off ramps to Route 2, the east approach being the Concord Turnpike cut-off and the northern approach being the Cambridge Turnpike. Each approach has two through lanes and an exclusive left-turn lane, with the exception of the southern approach (Route 2 Westbound off-ramp) which accommodates no left turns but does have an exclusive right turn lane. The proposed design of the at-grade intersection, with optimal signal timing and phasing is more than adequate to handle the forecast traffic volumes, functioning at LOS B in both the AM and PM peak hours.

1995 Intersection LOS

Time	Location	LOS	Delay
AM	Route 2 Ramps @ Cambridge Turnpike	B	9.0
PM	Route 2 Ramps @ Cambridge Turnpike	B	8.21

Ramp Analyses

Access to and from mainline Route 2 is completely grade separated. The design of the access ramps are single lane right hand entrance and exit ramps. Ramp analyses were performed at each of the four merge and or diverge points, for both the AM and PM peak hours.

The results of this analysis reveal that especially in the AM peak hour the eastbound off ramp would operate at level-of-service E, while in the PM, the westbound on ramp would operate at LOS D under 1995 build-year conditions.

Because of the poor functioning of the on and off ramps in the peak directions, a sensitivity analysis was performed, testing the benefits of an additional through lane on Route 2. The current design as proposed calls for two through lanes on Route 2. The results of the three through lane ramp analyses are presented below. These results demonstrate that the 3 through lanes do indeed provide adequate improvement of ramp functioning, raising the LOS to acceptable levels.

In addition to the sensitivity analysis to determine the effects of additional through lanes, a sensitivity analysis was also performed to assess the effects of grade on the ramp functioning. Under the current design, a significant grade of 6 percent would be present on the eastbound through travel lanes,

as well as a 2.5% grade on the westbound through travel lanes, in the vicinity of the on ramps. The ramp analyses program translates a significant freeway grade into higher passenger car equivalents for trucks, reflecting their slower speed as they climb the grade. Trucks traffic is also assumed to be present in the first or right hand lane in greater proportion than the other travel lanes. The results of the sensitivity analyses for grade are presented below. As can be seen from these results, flattening the grade would not remove the need for the additional through lane to bring the ramp functioning to acceptable levels.

1995 Ramp Analyses - AM

Location		2-lane	2-lane No-grade	3-lane	3-lane No-grade
W.B. Off	ramp	B	N/A	B	N/A
	freeway	C	N/A	C	N/A
E.B. On	ramp	D	C	B	A
	freeway	D	D	C	C
W.B. On	ramp	C	N/A	A	N/A
	freeway	C	N/A	C	N/A
E.B. Off	ramp	E	D	C	C
	freeway	E	D	C	C

1995 Ramp Analyses - PM

Location		2-lane	2-lane No-grade	3-lane	3-lane No-grade
W.B. Off	ramp	C	N/A	B	N/A
	freeway	D	N/A	C	N/A
E.B. On	ramp	C	C	A	A
	freeway	C	C	C	C
W.B. On	ramp	D	N/A	B	N/A
	freeway	D	N/A	C	N/A
E.B. Off	ramp	C	C	B	B
	freeway	C	C	C	C

Preliminary 2020 Forecasts

MHD design staff requested that CTPS develop some "preliminary" forecast volumes for the year 2020. While a more complete forecasting effort will be included in future work which will utilize the capabilities of the THE travel demand model, preliminary numbers were desired to determine a rough idea of what level of traffic volume growth could be accommodated by the proposed design. Two sources were used for the estimated yearly traffic volume growth rates. One was the forecast volumes in the Crosby's Corner vicinity that were developed for the years between 1990 and 1995 as part of the modeling process described above. Also, historic growth trends for Route 2 volumes entering and exiting the study area were determined. Based on these two sources, traffic volume can be expected to grow between 1% and 2% annually.

Therefore, two growth scenarios were developed, one a 1% per year growth rate and the other a 2% per year rate. The 1 % scenario consisted of a 1% per year growth rate applied to Route 2 mainline volumes and a 1/2% growth rate applied to side street approaches. The 2% per year growth rate scenario applied 2% to the mainline Route 2 volumes and 1% to the side street volumes. The factored mainline and side street volumes were then distributed to turning movements and ramp volumes based on the 1995 assigned traffic demand forecast volume distribution.

These forecast volumes were then used to assess the LOS functioning of the remaining at grade intersection and the Route 2 on and off ramps. Even if the growth rate were the lower, 1% rate, then some ramp level of service failure will occur with the 2 through lane design. With three through lanes the worst ramp LOS occurs with the AM eastbound off ramp under the 2% growth scenario. The results of the 2020 forecast volume ramp analyses are presented below.

2020 Future Year Ramp Analyses - AM

Location		2-lane 1%	3-lane 1%	2-lane 2%	3-lane 2%
W.B. Off	ramp	C	B	D	C
	freeway	D	C	E	C
E.B. On	ramp	F	B	F	C
	freeway	F	C	F	D
W.B. On	ramp	C	B	D	C
	freeway	D	C	E	C
E.B. Off	ramp	F	D	F	E
	freeway	F	D	F	E

2020 Future Year Ramp Analyses - PM

Location		2-lane 1%	3-lane 1%	2-lane 2%	3-lane 2%
W.B. Off	ramp	D	C	F	C
	freeway	E	C	F	D
E.B. On	ramp	C	A	E	B
	freeway	D	C	F	C
W.B. On	ramp	E	C	F	C
	freeway	E	C	F	D
E.B. Off	ramp	D	C	F	C
	freeway	D	C	F	D

The preliminary through volume forecasts may be overestimated because they do not take into account the constraining effects of the adjacent signalized intersections. In the westbound direction the "upstream" intersection of Route 2 at Bedford Road serves as a "meter" due to the limitations of a signalized intersection to process through volume. In the eastbound direction the intersection of Route 126 and Route 2 limits the through volume flow reaching the Crosby's Corner intersection. These effects are particularly pronounced in the peak direction for the am and pm peak hours. The Route 126 intersection is especially constrained in its Route 2 through volume capacity due to heavy Route 126 volumes. Therefore, the preliminary growth rate derived volume forecasts will never actually materialize at the Crosby's Corner interchange, unless substantial improvements are made to these adjacent intersections. The following table presents the results of the level of service analysis of the adjacent intersections with the forecast levels of through volumes.

Signalized Intersection Analyses - AM

Location	1995 LOS	1995 Delay	2020 1% LOS	2020 1% Delay	2020 2% LOS	2020 2% Delay
Route 2 @ Bedford Road	C	24.1	F	92.9	F	Infin.
Route 2 @ Route 126	D	37.9	F	87.7	F	Infin.
Route 2 Ramps @ Cambridge Turn.	B	8.12	B	8.54	B	8.93

Signalized Intersection Analyses - PM

Location	1995 LOS	1995 Delay	2020 1% LOS	2020 1% Delay	2020 2% LOS	2020 2% Delay
Route 2 @ Bedford Road	B	9.0	E	48.7	F	967
Route 2 @ Route 126	D	29.7	F	131.0	F	Infin.
Route 2 Ramps @ Cambridge Turn.	B	8.21	B	8.65	B	8.75

The table presented below illustrates the magnitude of the difference between the forecast through volumes and the amount of through volume the intersections can safely "process" as defined by LOS C. The volumes are for the peak direction only, namely, eastbound in the AM and westbound in the PM.

Through Volume Comparison - AM

Location	LOS C Through Vol.	2020 1% Through Vol.	2020 2% Through Vol.
Route 2 @ Bedford Road	N/A	3098	4097
Route 2 @ Route 126	2300	3254	3994

Through Volume Comparison - PM

Location	LOS C Through Vol.	2020 1% Through Vol.	2020 2% Through Vol.
Route 2 @ Bedford Road	2800	3061	3987
Route 2 @ Route 126	N/A	2953	3913

Conclusion

The following conclusions can be reached as a result of these analyses. Even with modest growth in traffic volumes, the Crosby's Corner design alternative as currently proposed will experience some operational delays at peak direction ramp

junctions during the peak hours. Further efforts to reduce the grade in the eastbound direction will not have significant benefits for the ramp junctions operational level of service. The addition of a third through lane would provide sufficient benefit at build-year and projected traffic volume levels to bring operational level of service to acceptable levels.

The remaining at-grade intersection of the Route 2 ramps and the Cambridge Turnpike Cut-off will operate within acceptable LOS standards under all forecast scenarios.

In addition, other adjacent Route 2 signalized intersections will be constrained and unable to process additional through volumes during the peak hours. (In the PM, Route 2 @ Route 126 is already functioning below LOS C).

MEMORANDUM

November 4, 1996

TO: ROUTE 2 CORRIDOR ADVISORY COMMITTEE: TOWN REPRESENTATIVES
FROM: JOHN R. CASWELL, LINCOLN TRAFFIC MANAGEMENT COMMITTEE
SUBJECT: CTPS COMPUTER MODEL

I met with Ms. Efi Pagitsas and Ms Alicia Wilson at CTPS on 22 October 1996. I used the memorandum of 9/12/96 "Meeting Notes" as the basis for my discussion.

The computer model CTPS is using to make traffic predictions is fairly straightforward. It accepts vehicles coming into the modeled area and finds the shortest route for them through the maze of the streets of the model to their destination which is either inside or outside the modeled area. The model assigns " impedances" to the streets of the model so that the "shortest" route is the "quickest" route. Things that make up impedances include the number of cars - amount of traffic - on a road, stop lights, corners, business districts, etc. The model uses a mathematical expression called the Moore Algorithm to find this shortest path through the maze.

The number of cars traveling the roads is arrived at through the use of a "Trip Generation" algorithm or model. The CTPS uses a "gravity" model, which they say is quite standard. As I understand this, it takes the number of sources of cars - households from census data -in given zones within and outside the modeled area and the number of "attractions" or destinations in all these zones, and then concludes that the destinations attract the sources much as objects are attracted to one another by gravity. The paths of these sources to their destinations are the impeded roads of the area - the trip through the maze.

This work produces a number of cars on the various roads of the area. The CTPS then goes into the field and counts cars and especially, turning movements at given locations. They then go back and rerun the model in a successive iteration mode until they get the model numbers to agree as closely as possible with the observed counts and movements. This is the calibration of the model with the real world. The end result is a map with all the numbers on it, and is what decisions and proposals are based on.

I would have to say that the trip generation part of the work appears to be the weakest. I am not sure whether the model tries to guess at the number of cars per source based on the number of people in a given household, but obviously this factor is a of great importance. Note that it does not/ cannot take into account commercial traffic because the sources are not commercial entities, but are homes derived from censuses. This means that the only way commercial vehicles' contribution to traffic is accounted for is through the field observations and counts and the successive iteration of the model. Second, as Efie pointed out. the field observations are truly a snapshot in time, for they are done over a matter of hours on only one day. Even though they are done at several points, one day's observation is statistically very small. The CTPS also tries to note license plate numbers in order to help in its calibration of sources, but even with video cameras the amount of data is relatively small, and takes an inordinate amount of data reduction time - copying license plates from the video and then running them through the Registry. Inaccuracies occur too due to students and, in our case, HAFB residents with out of state plates.

Can there be greater accuracy? Yes, in limited circumstances and in limited times. Employers can be asked to supply zip code data of their personnel. This will help greatly for rush hour counts, especially the morning ones (afternoon counts get all mixed up with shopping, after school errands and trips, etc.). Calibration possibly could be done so as to include data from as many points as possible using traffic counters. This would obtain data over longer periods of time, like a week, and thus might be more representative and accurate. However, counters too can have problems such as not differentiating between a bicycle and a car, and they do not observe license plates..

To the point of the six concerns in the Meeting Notes memo:

1 and 2. Anytime the model is "calibrated" or rerun iteratively, there will be changes in the baseline numbers. The numbers for our various alternatives change with changes to the physical aspects of an interchange, rotary, etc. or the geometry of the road design for this changes the impedances within the maze and thus the shortest/quickest routes from the sources to the destinations. The change to the numbers for one of the alternatives involving the Rt 62 - ORNAC - Rt 2 area occurred because of a mistake in inputing the alternative to the model: a 60 foot ramp was input as 600 feet, and the difference in resulting impedances was large enough to greatly affect the number of cars using the ramp and the turnings there.

3. Sources are determined from zones which in turn are assigned a point of origin so that vehicles can emanate from that point and be assigned to travel over the various roads by the model. I would always like to see more detail in the zones outside the modeled area, and in our case, especially to the north and south. However, the model as it stands does attempt to take north-south traffic into account.

4. Note the comment above re afternoon rush hour and the mix that occurs then.

5. I asked the specific question about the earlier Concord Rotary model work which indicated acceptable operation and which was questioned. Efie was quick to point out that at that time the CTPS said only that "the model" predicted acceptable performance, not the CTPS, and that was why a different model was then used.

6. That the model does not indicate a great change of local road traffic to Rt 2 traffic seems to be counter intuitive. I would guess that there will be a change in local traffic shifting to Rt 2, but it probably won't be as great as we would anticipate. Models are only estimators. If this one can predict + or - 10% of the real world, I think that is all we can get out of it. Thus I agree with Efie and Alicia that its benefit is to indicate trends, not numbers to a high degree of accuracy. Certainly, because I am not overly happy with the trip generation method used, nor the sparsity of data used in the calibration, I would not expect much more. I would be very suspect, for example, if an alternative, showed up with large changes in the traffic predictions over the baseline, unless the alternative were a drastic change in the impedances within the modeled area. A change to a multilane limited access highway from Rt 495 to downtown Boston with an increase in the capacity of Rt 128 as well, would, to me, be drastic enough to produce big number changes. So would the dead ending of Elm Street, for example.

In summary, the CTPS computer model doing traffic assignment does it in a logical manner. Its results are only as good as its inputs. The Trip Generation model does not satisfy me, but I hasten to say I haven't come up with anything better. The calibration data could be enhanced, but whether it would produce greatly different numbers can only be proven by doing it, and rerunning the model which is time consuming.

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CENTRAL
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MEMORANDUM

TO: **John Caswell**
Lincoln Traffic Management Committee

November 5, 1996

FROM: **Efi Pagitsas and Alicia Powell Wilson**

RE: **Comments on Your Memo about the CTPS Route 2 Computer Model**

Your memo presents a good summary of the modeling issues discussed during our meeting on October 22nd. There are several points, however, that need to be clarified. These are listed below:

Second paragraph: "Corners and business districts" are not explicitly considered by the model. It would be more appropriate to state that "Impedances include the number of cars - amount of traffic - on a road, speeds, and the capacity per lane."

Third paragraph, first sentence: We think you mean **trip distribution** algorithm not **trip generation** algorithm.

Fifth paragraph, first and second sentences: Yes, the model does use households by income category to determine the number of trips generated or "produced" at the home end. These trips are "attracted" to zones based on the degree of retail and non-retail employment located within zonal boundaries and on the distance between zones. THE uses the gravity model to create a **seed or initial** trip table and to distribute the trips on the highway network. Yes, the **seed** table contains only auto trips since THE extracts auto driver trips from total trips during trip generation. However, during model calibration, the general distribution of trips is adjusted upward or downward to include all types of vehicle trips based on observed traffic counts. The **seed** trip table is never used to make final trip assignments. Also note that even though the assignment results presented to you are for a peak hour, all trip types (i.e., home based work, home based non-work, and non-home based) are included. Rest assured that even though we can not tell you explicitly what proportion of total trips they represent, commercial trips are accounted for during a given time period as observed counts were available on 60 percent of the links.

Fifth paragraph, fourth sentence: Yes, turning movement counts for a particular intersection are usually done for a few hours on one given day. This is standard practice with all models. These counts, however, are never used "as is". They are compared with available historic data and traffic flows are balanced from one intersection to another.

Since all intersections are not counted on the same day, daily variation (if any) is taken into account. Note that various studies have indicated that peak period traffic is fairly consistent from day to day.

Sixth paragraph, fifth sentence: Automatic Traffic Recorder (ATR) counts (particularly on connectors to external zones) were used in the model. These counts were taken on a continuous basis over a 48 to 72 hour period during midweek.

Seventh paragraph, second sentence: "Baseline" Or Base Case numbers do not change after a model is calibrated.

Eighth paragraph, second sentence: We feel that the modeled area is large enough to take care of diversions. Remember that the modeled area is larger than the area shown on the presentation maps. The area includes all of Lexington and extends into Burlington. To insure that diversions were not missed, Alternative E, which includes the most build options, was tested with the full regional model. No significant diversions to Route 2 were found.

Tenth paragraph, second sentence: ...that was why a different **analytical method** (not model)...

Eleventh paragraph: Following our meeting with you last month, it is not clear to us why you are not happy with the trip generation and distribution method and why you think that the data used to calibrate the model is sparse when new turning movement counts were performed at 15 intersections and directional ATR counts were performed at another 15 locations. In addition, as was stated earlier, counts were available for 60% of all links.

Finally, regarding your and the CAC's concerns about truck traffic, as we discussed during our meeting last month, CTPS and MAPC are working on a project to provide truck exclusion and truck diversion routes for the Route 2 study towns.

Please call Efi at 973-7106 or Alicia at 973-8008 if you have additional questions.

cc: Dan Beagan, MHD
Karl Quackenbush, CTPS