BOSTON UNIVERSITY

Sepideh Pourazarm <sepid@bu.edu>

INRIX data and capacities - explanation and times to meet

7 messages

Scott Peterson <speterson@ctps.org> Wed, Jul 8, 2015 at 9:48 AM
To: Sepideh Pourazarm <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>
Cc: "Cassandras, Christos G" <cgc@bu.edu>, Conor Gately <cgately@gmail.com>

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our model is NOT to determine the roadway capacity. Instead, it is to approximate how travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the

volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate (area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again, our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

- Mon 7/13 after 3PM
- Tues 7/14 after 3PM
- Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

> *** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

  The modeled (calculated) “Total roadway capacity for the period of time ” means the capacity of roadway for all available lanes for time period AM (3hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the “capacity” (LOS F) of a road. In your email, you use the word “traffic jam”. This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don’t have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM

procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- "Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

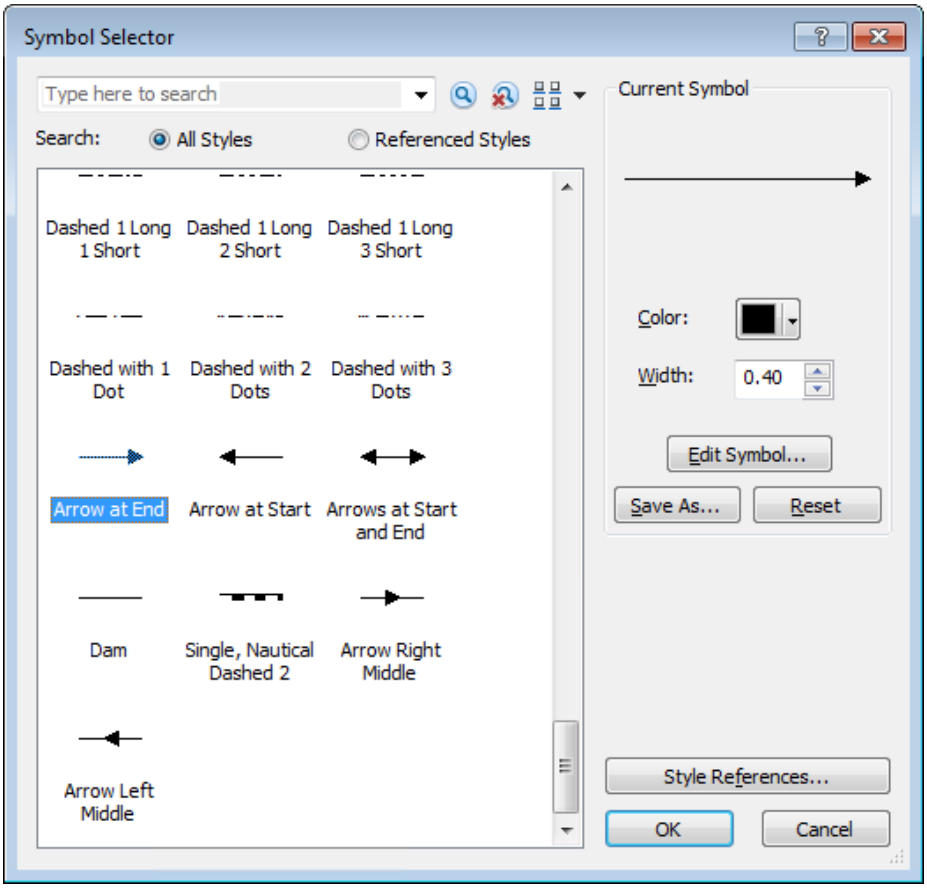
The time period definition in shape file

- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm
- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "

** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?

I wonder if you can explain what you mean by "at a level of surface of C".

> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.

**I think I have them in the attribute table as bellow:

SCEN_00_AB=AB_AM_Lanes

SCEN_00_BA=BA_AM_Lanes

SCEN_00_A1=AB_MD_Lanes

SCEN_00_B1=BA_MD_Lanes

SCEN_00_A2=AB_PM_Lanes

SCEN_00_B2=BA_PM_Lanes

SCEN_00_A3=AB_NT_Lanes

SCEN_00_B3=BA_NT_Lanes

Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.

I wonder if you can give me any idea how I should match capacity data with the INRIX data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

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Sepideh Pourazarm

PhD Candidate

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Boston, MA 02215

On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM

To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2nd of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh

Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of great help to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
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>
> <image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM
To: Scott Peterson; Conor Gately; Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
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Cassandras, Christos G <cgc@bu.edu> Wed, Jul 8, 2015 at 1:23 PM
To: Scott Peterson <speterson@ctps.org>, "Pourazarm, Sepideh" <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>

Hi Scott…

Thank you VERY MUCH for taking the time to describe the concept of capacity as you use it and, more generally, your modeling approach. This has been very helpful for me to read and to get a much better idea of what your thinking process is.

First, this clarifies how you define "capacity". Sepideh and I had a meeting yesterday and we had pretty much reached the conclusion that you are viewing it as the "maximum number of vehicles that can travel past a single point", that is, as a flow given a specific vehicle speed. We can work with that now that we understand it.

Second, I must agree with you that models for travel time as a function of demand have

been "studied to death". In fact, the BPR function and all other similar models you mention are all variants of a fundamental relationship from elementary queueing theory adapted to traffic systems. We have been using the "conical delay function" in our work for optimal traffic routing, but any other function would work just as well, so we are happy to go with whatever is commonly used in Boston or that you specifically recommend.

Once a delay function is selected, its exact shape depends on the values of certain parameters (such as the alpha, beta values you mention). For us, "capacity" is such a parameter and it normally captures the value at which a resource saturates. In traffic models, that's the parameter value at which a road segment reaches the point where the function that gives vehicle speed as a function of demand takes on the value zero (i.e., a full jam). That's why we have been seeking a constant value for "capacity". But as I mentioned above, now that we understand things we can work with the notion of capacity you use.

I should point out that some of our work is model-independent, that is we aim to determine optimal routing decisions or optimal dynamic traffic light cycles without having to know specific delay functions or parameter values. This is made possible by the increasing availability of data (such as the INRIX data set) which is moving us towards data-driven methods rather than model-driven ones (as long as one has a structural model in place – like conservation of flow equations – but no detailed mathematical functions).

Also, I now understand why you use "period capacity factors" to "represent peak hour conditions within a period". In a Monte Carlo type simulation of a traffic system, one would capture the fluctuations in traffic flows through random processes. But if you are not simulating at this level of detail, then what you describe attempts to capture reasonable average behavior.

About a meeting:

It turns out that I have to be at City Hall next Wednesday for a 3-4pm meeting with the Office of New Urban Mechanics and some DPW people. Depending on where you are located, I thought this might make it easier for you so that we could meet there earlier or at 4pm that day.

If that does not work (I don't see Wed in your list of available dates), then Thurs or Fri next week works for me. If this is preferable, then how about Thurs at 1pm?

Regards,

Christos

****

* Christos G. Cassandras

* Distinguished Professor of Engineering

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* Head, Division of Systems Engineering, and

* Professor of Electrical and Computer Engineering

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Wednesday, July 08, 2015 9:48 AM
To: Pourazarm, Sepideh; Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately
Subject: INRIX data and capacities - explanation and times to meet

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our

model is NOT to determine the roadway capacity. Instead, it is to approximate how travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate (area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again, our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

- Mon 7/13 after 3PM
- Tues 7/14 after 3PM
- Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

The modeled (calculated) "Total roadway capacity for the period of time " means the capacity of roadway for all available lanes for time period AM (3hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the “capacity” (LOS F) of a road. In your email, you use the word “traffic jam”. This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don’t have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- "Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

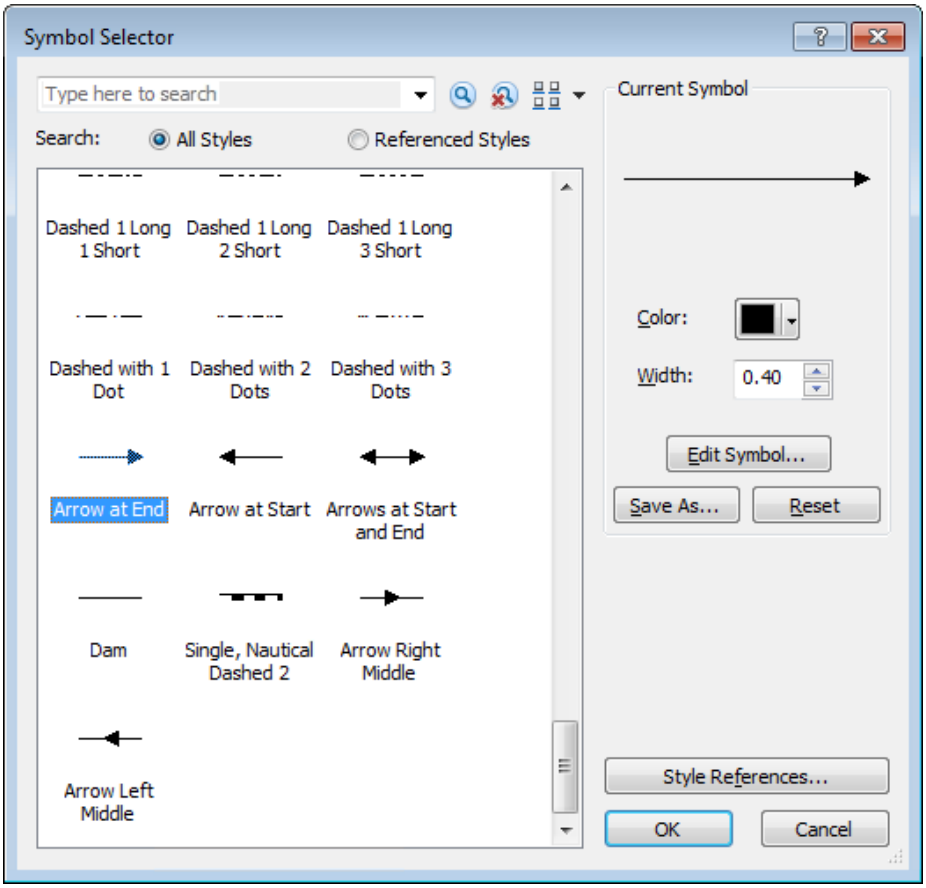
The time period definition in shape file

- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm
- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "
>
> ** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?
>
> I wonder if you can explain what you mean by "at a level of surface of C".
>
> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.
>
> **I think I have them in the attribute table as bellow:
>
> SCEN_00_AB=AB_AM_Lanes
>
> SCEN_00_BA=BA_AM_Lanes
>
> SCEN_00_A1=AB_MD_Lanes
>
> SCEN_00_B1=BA_MD_Lanes
>
> SCEN_00_A2=AB_PM_Lanes
>
> SCEN_00_B2=BA_PM_Lanes
>
> SCEN_00_A3=AB_NT_Lanes
>
> SCEN_00_B3=BA_NT_Lanes
>
> Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.
>
> I wonder if you can give me any idea how I should match capacity data with the INRIX data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

--

Sepideh Pourazarm

PhD Candidate

Center for Information and Systems Engineering
Boston University
8 St. Mary's St.
Boston, MA 02215

On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

****
* Christos G. Cassandras
* Distinguished Professor of Engineering
*
* Head, Division of Systems Engineering, and
* Professor of Electrical and Computer Engineering
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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2nd of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh
Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of great help to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
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>
> <image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM
To: Scott Peterson; Conor Gately; Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and

predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
> CENTRAL TRANSPORTATION PLANNING STAFF
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>
> <image001.png>

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* Christos G. Cassandras

* Distinguished Professor of Engineering

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* Head, Division of Systems Engineering, and

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*    Professor of Electrical and Computer Engineering
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Scott Peterson <speterson@ctps.org> Wed, Jul 8, 2015 at 2:36 PM
To: "Cassandras, Christos G" <cgc@bu.edu>, "Pourazarm, Sepideh" <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>

Hello Christos,

I just had some time open up on Wed., between 12:30-3PM.

How about 2PM at the City Hall (is there a room available?) or we could meet for coffee at a place nearby.

My office is about a 10-15 min walk from City Hall, CTPS is across the Green Line Boylston St Station and has several conference rooms, if we are lacking a meeting space.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Wednesday, July 08, 2015 1:24 PM
To: Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
Subject: RE: INRIX data and capacities - explanation and times to meet

Hi Scott…

Thank you VERY MUCH for taking the time to describe the concept of capacity as you use it and, more generally, your modeling approach. This has been very helpful for me to read and to get a much better idea of what your thinking process is.

First, this clarifies how you define "capacity". Sepideh and I had a meeting yesterday and we had pretty much reached the conclusion that you are viewing it as the "maximum number of vehicles that can travel past a single point", that is, as a flow given a specific vehicle speed. We can work with that now that we understand it.

Second, I must agree with you that models for travel time as a function of demand have been "studied to death". In fact, the BPR function and all other similar models you mention are all variants of a fundamental relationship from elementary queueing theory adapted to traffic systems. We have been using the "conical delay function" in our work for optimal traffic routing, but any other function would work just as well, so we are happy to go with whatever is commonly used in Boston or that you specifically recommend.

Once a delay function is selected, its exact shape depends on the values of certain parameters (such as the alpha, beta values you mention). For us, "capacity" is such a parameter and it normally captures the value at which a resource saturates. In traffic models, that's the parameter value at which a road segment reaches the point where the function that gives vehicle speed as a function of demand takes on the value zero (i.e., a full jam). That's why we have been seeking a constant value for "capacity". But as I mentioned above, now that we understand things we can work with the notion of capacity you use.

I should point out that some of our work is model-independent, that is we aim to determine optimal routing decisions or optimal dynamic traffic light cycles without having to know specific delay functions or parameter values. This is made possible by the increasing availability of data (such as the INRIX data set) which is moving us towards data-driven methods rather than model-driven ones (as long as one has a structural model in place – like conservation of flow equations – but no detailed mathematical functions).

Also, I now understand why you use "period capacity factors" to "represent peak hour

conditions within a period". In a Monte Carlo type simulation of a traffic system, one would capture the fluctuations in traffic flows through random processes. But if you are not simulating at this level of detail, then what you describe attempts to capture reasonable average behavior.

About a meeting:

It turns out that I have to be at City Hall next Wednesday for a 3-4pm meeting with the Office of New Urban Mechanics and some DPW people. Depending on where you are located, I thought this might make it easier for you so that we could meet there earlier or at 4pm that day.

If that does not work (I don't see Wed in your list of available dates), then Thurs or Fri next week works for me. If this is preferable, then how about Thurs at 1pm?

Regards,

Christos

****
* Christos G. Cassandras
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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Wednesday, July 08, 2015 9:48 AM
To: Pourazarm, Sepideh; Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately
Subject: INRIX data and capacities - explanation and times to meet

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our model is NOT to determine the roadway capacity. Instead, it is to approximate how travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and

others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate (area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again, our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

- Mon 7/13 after 3PM
- Tues 7/14 after 3PM
- Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

The modeled (calculated) “Total roadway capacity for the period of time ” means the capacity of roadway for all available lanes for time period AM (3hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you

should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the "capacity" (LOS F) of a road. In your email, you use the word "traffic jam". This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don't have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- "Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

The time period definition in shape file

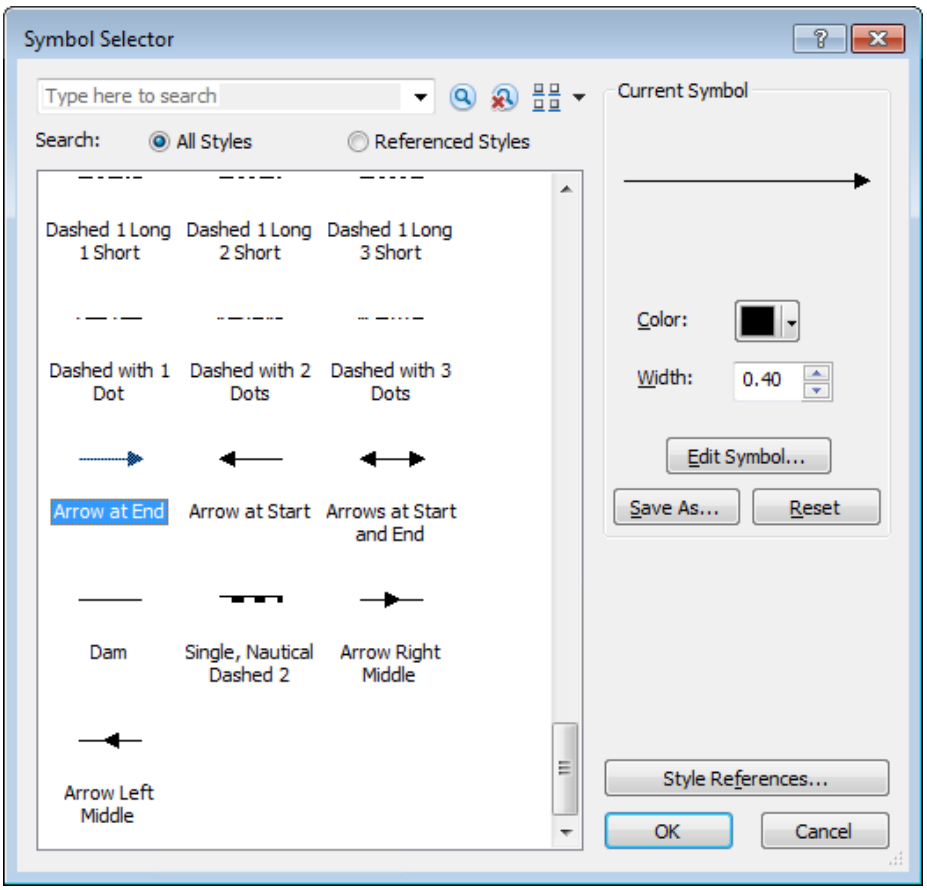
- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm

- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "
>
> ** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?
>
> I wonder if you can explain what you mean by "at a level of surface of C".
>
> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.
>
> **I think I have them in the attribute table as bellow:
>
> SCEN_00_AB=AB_AM_Lanes
>
> SCEN_00_BA=BA_AM_Lanes

SCEN_00_A1=AB_MD_Lanes

SCEN_00_B1=BA_MD_Lanes

SCEN_00_A2=AB_PM_Lanes

SCEN_00_B2=BA_PM_Lanes

SCEN_00_A3=AB_NT_Lanes

SCEN_00_B3=BA_NT_Lanes

Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.

I wonder if you can give me any idea how I should match capacity data with the INRIX data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

--

Sepideh Pourazarm

PhD Candidate

Center for Information and Systems Engineering
Boston University
8 St. Mary's St.
Boston, MA 02215

On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

****

* Christos G. Cassandras

* Distinguished Professor of Engineering

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* Professor of Electrical and Computer Engineering

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******  WWW:    http://people.bu.edu/cgc

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2nd of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh
Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of great help to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
> CENTRAL TRANSPORTATION PLANNING STAFF
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<image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM
To: Scott Peterson; Conor Gately; Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott

Scott A. Peterson | Director of Technical Services

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* Christos G. Cassandras

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Sepideh Pourazarm

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Cassandras, Christos G <cgc@bu.edu> Wed, Jul 8, 2015 at 3:44 PM
To: Scott Peterson <speterson@ctps.org>, "Pourazarm, Sepideh" <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>

I just had some time open up on Wed., between 12:30-3PM.

How about 2PM at the City Hall (is there a room available?) or we could meet for coffee at a place nearby.

My office is about a 10-15 min walk from City Hall, CTPS is across the Green Line Boylston St Station and has several conference rooms, if we are lacking a meeting space.

*** That's good! Let me first see if we can get a room at City Hall at 2pm. If not, I would opt for the nearby coffee shop option (I know there are plenty) only because time is short and it would save the walk time from your office to my 3pm meeting. At some point, we probably need a longer meeting with a screen and board, but let's take advantage of what we have now.

I'll get back to you asap once I talk to our friends at the MONUM.

Christos

==========

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Wednesday, July 08, 2015 1:24 PM
To: Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
Subject: RE: INRIX data and capacities - explanation and times to meet

Hi Scott…

Thank you VERY MUCH for taking the time to describe the concept of capacity as you

use it and, more generally, your modeling approach. This has been very helpful for me to read and to get a much better idea of what your thinking process is.

First, this clarifies how you define “capacity”. Sepideh and I had a meeting yesterday and we had pretty much reached the conclusion that you are viewing it as the “maximum number of vehicles that can travel past a single point”, that is, as a flow given a specific vehicle speed. We can work with that now that we understand it.

Second, I must agree with you that models for travel time as a function of demand have been “studied to death”. In fact, the BPR function and all other similar models you mention are all variants of a fundamental relationship from elementary queueing theory adapted to traffic systems. We have been using the “conical delay function” in our work for optimal traffic routing, but any other function would work just as well, so we are happy to go with whatever is commonly used in Boston or that you specifically recommend.

Once a delay function is selected, its exact shape depends on the values of certain parameters (such as the alpha, beta values you mention). For us, “capacity” is such a parameter and it normally captures the value at which a resource saturates. In traffic models, that’s the parameter value at which a road segment reaches the point where the function that gives vehicle speed as a function of demand takes on the value zero (i.e., a full jam). That’s why we have been seeking a constant value for “capacity”. But as I mentioned above, now that we understand things we can work with the notion of capacity you use.

I should point out that some of our work is model-independent, that is we aim to determine optimal routing decisions or optimal dynamic traffic light cycles without having to know specific delay functions or parameter values. This is made possible by the increasing availability of data (such as the INRIX data set) which is moving us towards data-driven methods rather than model-driven ones (as long as one has a structural model in place – like conservation of flow equations – but no detailed mathematical functions).

Also, I now understand why you use “period capacity factors” to “represent peak hour conditions within a period”. In a Monte Carlo type simulation of a traffic system, one would capture the fluctuations in traffic flows through random processes. But if you are not simulating at this level of detail, then what you describe attempts to capture reasonable average behavior.

About a meeting:

It turns out that I have to be at City Hall next Wednesday for a 3-4pm meeting with the Office of New Urban Mechanics and some DPW people. Depending on where you are located, I thought this might make it easier for you so that we could meet there earlier or at 4pm that day.

If that does not work (I don’t see Wed in your list of available dates), then Thurs or Fri next week works for me. If this is preferable, then how about Thurs at 1pm?

Regards,

Christos

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Wednesday, July 08, 2015 9:48 AM
To: Pourazarm, Sepideh; Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately
Subject: INRIX data and capacities - explanation and times to meet

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our model is NOT to determine the roadway capacity. Instead, it is to approximate how travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate (area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again,

our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

Mon 7/13 after 3PM

Tues 7/14 after 3PM

Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

The modeled (calculated) "Total roadway capacity for the period of time " means the capacity of roadway for all available lanes for time period AM (3hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the “capacity” (LOS F) of a road. In your email, you use the word “traffic jam”. This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don’t have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- "Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

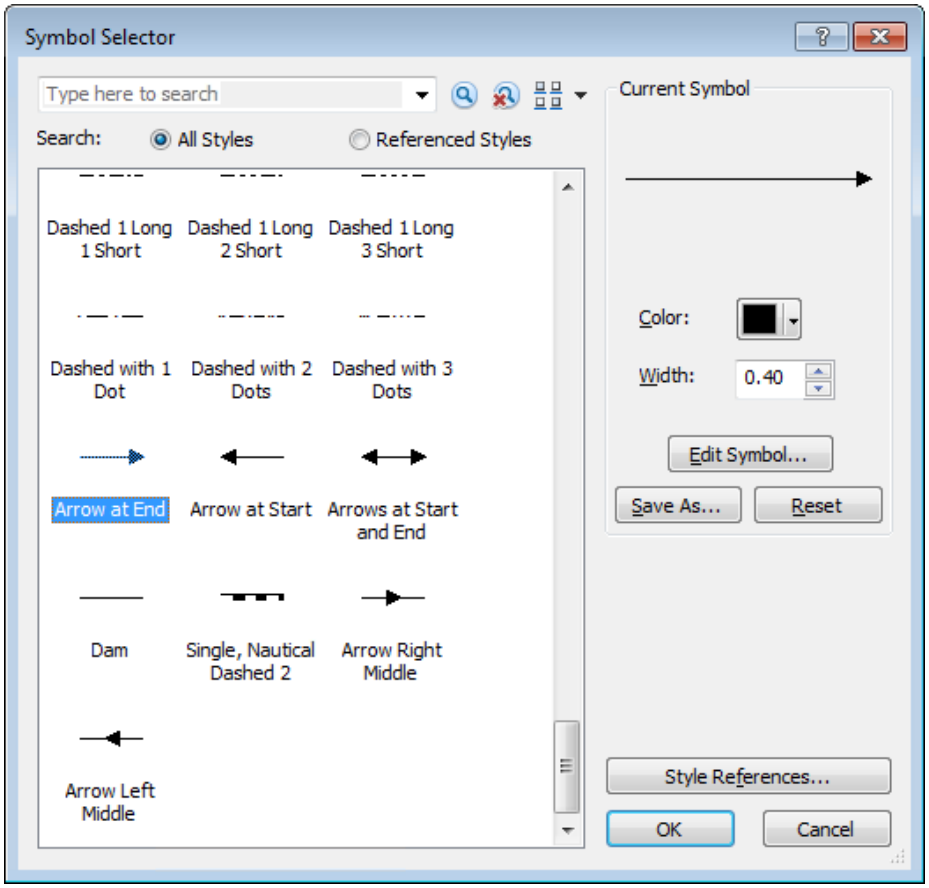
The time period definition in shape file

- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm
- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "
>
> ** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?
>
> I wonder if you can explain what you mean by "at a level of surface of C".
>
> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.
>
> **I think I have them in the attribute table as bellow:
>
> SCEN_00_AB=AB_AM_Lanes
>
> SCEN_00_BA=BA_AM_Lanes
>
> SCEN_00_A1=AB_MD_Lanes
>
> SCEN_00_B1=BA_MD_Lanes
>
> SCEN_00_A2=AB_PM_Lanes
>
> SCEN_00_B2=BA_PM_Lanes
>
> SCEN_00_A3=AB_NT_Lanes
>
> SCEN_00_B3=BA_NT_Lanes

Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.

I wonder if you can give me any idea how I should match capacity data with the INRIX data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

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Sepideh Pourazarm

PhD Candidate

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On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

****
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*
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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson

Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2nd of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh
Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of great help to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
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> www.ctps.org/bostonmpo
>
> <image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM
To: Scott Peterson; Conor Gately; Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
> CENTRAL TRANSPORTATION PLANNING STAFF
> **857.702.3683** | speterson@ctps.org
> www.ctps.org/bostonmpo
>
> <image001.png>

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Cassandras <cgc@bu.edu> Mon, Jul 13, 2015 at 2:23 PM
To: Scott Peterson <speterson@ctps.org>, "Pourazarm, Sepideh" <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>

Scott:

I have secured a room for us to meet at City Hall 2-3pm on Wednesday. This is courtesy of Chris Osgood and Nigel Jacob. Let's meet at 2pm at the Mayor's Office on the 5th Floor of City Hall. Sepideh and I will be there, but just in case you arrive before us, please ask for either Chris or Nigel.

Sepideh and I will have some ppt slides to set the stage so we can then discuss issues of model and data interpretation, seek answer to some more questions we have, and also look forward to some of our project goals and get feedback and suggestions from you.

Regards, Christos

==========

On 7/8/2015 3:44 PM, Cassandras, Christos G wrote:

I just had some time open up on Wed., between 12:30-3PM.

How about 2PM at the City Hall (is there a room available?) or we could meet for coffee at a place nearby.

My office is about a 10-15 min walk from City Hall, CTPS is across the Green Line Boylston St Station and has several conference rooms, if we are lacking a meeting space.

*** That's good! Let me first see if we can get a room at City Hall at 2pm. If not, I would opt for the nearby coffee shop option (I know there are plenty) only because time is short and it would save the walk time from your office to my 3pm meeting. At some point, we probably need a longer meeting with a screen and board, but let's take advantage of what we have now.

I'll get back to you asap once I talk to our friends at the MONUM.

Christos

==========

Regards,

Scott

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Wednesday, July 08, 2015 1:24 PM
To: Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
Subject: RE: INRIX data and capacities - explanation and times to meet

Hi Scott…

Thank you VERY MUCH for taking the time to describe the concept of capacity as you use it and, more generally, your modeling approach. This has been very helpful for me to read and to get a much better idea of what your thinking process is.

First, this clarifies how you define “capacity”. Sepideh and I had a meeting yesterday and we had pretty much reached the conclusion that you are viewing it as the “maximum number of vehicles that can travel past a single point”, that is, as a flow given a specific vehicle speed. We can work with that now that we understand it.

Second, I must agree with you that models for travel time as a function of demand have been “studied to death”. In fact, the BPR function and all other similar models you mention are all variants of a fundamental relationship from elementary queueing theory adapted to traffic systems. We have been using the “conical delay function” in our work for optimal traffic routing, but any other function would work just as well, so we are happy to go with whatever is commonly used in Boston or that you specifically recommend.

Once a delay function is selected, its exact shape depends on the values of certain parameters (such as the alpha, beta values you mention). For us, “capacity” is such a parameter and it normally captures the value at which a resource saturates. In traffic models, that’s the parameter value at which a road segment reaches the point where the function that gives vehicle speed as a function of demand takes on the value zero (i.e., a full jam). That’s why we have been seeking a constant value for “capacity”. But as I mentioned above, now that we understand things we can work with the notion of capacity you use.

I should point out that some of our work is model-independent, that is we aim to determine optimal routing decisions or optimal dynamic traffic light cycles without having to know specific delay functions or parameter values. This is made possible by the increasing availability of data (such as the INRIX data set) which is moving us towards data-driven methods rather than model-driven ones (as long as one has a structural model in place – like conservation of flow equations – but no detailed mathematical functions).

Also, I now understand why you use “period capacity factors” to “represent peak hour conditions within a period”. In a Monte Carlo type simulation of a traffic system, one would capture the fluctuations in traffic flows through random processes. But if you are not simulating at this level of detail, then what you describe attempts to capture reasonable average behavior.

About a meeting:

It turns out that I have to be at City Hall next Wednesday for a 3-4pm meeting with the Office of New Urban Mechanics and some DPW people. Depending on where you are located, I thought this might make it easier for you so that we could meet there earlier or at 4pm that day.

If that does not work (I don’t see Wed in your list of available dates), then Thurs or Fri next week works for me. If this is preferable, then how about Thurs at 1pm?

Regards,

Christos

****

* Christos G. Cassandras

* Distinguished Professor of Engineering

*

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Wednesday, July 08, 2015 9:48 AM
To: Pourazarm, Sepideh; Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately
Subject: INRIX data and capacities - explanation and times to meet

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our model is NOT to determine the roadway capacity. Instead, it is to approximate how

travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate (area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again, our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a

volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

Mon 7/13 after 3PM

Tues 7/14 after 3PM

Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

The modeled (calculated) "Total roadway capacity for the period of time " means the capacity of roadway for all available lanes for time period AM (3hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the “capacity” (LOS F) of a road. In your email, you use the word “traffic jam”. This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don’t have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- "Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

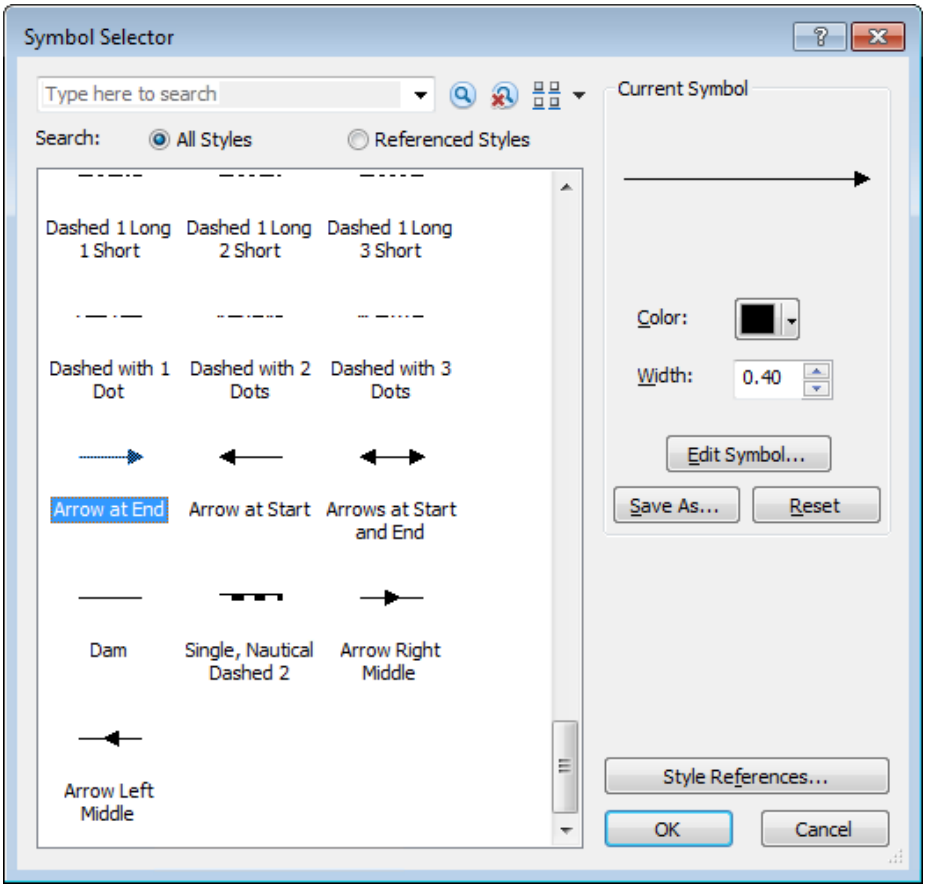
The time period definition in shape file

- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm
- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "
>
> ** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?
>
> I wonder if you can explain what you mean by "at a level of surface of C".
>
> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.
>
> **I think I have them in the attribute table as bellow:
>
> SCEN_00_AB=AB_AM_Lanes
>
> SCEN_00_BA=BA_AM_Lanes
>
> SCEN_00_A1=AB_MD_Lanes
>
> SCEN_00_B1=BA_MD_Lanes
>
> SCEN_00_A2=AB_PM_Lanes
>
> SCEN_00_B2=BA_PM_Lanes
>
> SCEN_00_A3=AB_NT_Lanes

SCEN_00_B3=BA_NT_Lanes

Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.

I wonder if you can give me any idea how I should match capacity data with the INRIX data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

--

Sepideh Pourazarm

PhD Candidate

Center for Information and Systems Engineering
Boston University
8 St. Mary's St.
Boston, MA 02215

On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

****

* Christos G. Cassandras

* Distinguished Professor of Engineering

*

* Head, Division of Systems Engineering, and

* Professor of Electrical and Computer Engineering

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2nd of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh
Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of great help

to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
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>
> <image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM
To: Scott Peterson; Conor Gately; Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
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> **857.702.3683** | speterson@ctps.org
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>
> <image001.png>

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* Christos G. Cassandras

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**********************************************************
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Scott Peterson <speterson@ctps.org> Mon, Jul 13, 2015 at 5:34 PM
To: Cassandras <cgc@bu.edu>, "Pourazarm, Sepideh" <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>

Great, see you then!

Scott A. Peterson | Director of Technical Services

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From: Cassandras [mailto:cgc@bu.edu]
Sent: Monday, July 13, 2015 2:24 PM
To: Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
Subject: Re: INRIX data and capacities - explanation and times to meet

Scott:

I have secured a room for us to meet at City Hall 2-3pm on Wednesday. This is courtesy of Chris Osgood and Nigel Jacob. Let's meet at 2pm at the Mayor's Office on the 5th Floor of City Hall. Sepideh and I will be there, but just in case you arrive before us, please ask for either Chris or Nigel.

Sepideh and I will have some ppt slides to set the stage so we can then discuss issues of model and data interpretation, seek answer to some more questions we have, and also look forward to some of our project goals and get feedback and suggestions from you.

Regards, Christos

==========

On 7/8/2015 3:44 PM, Cassandras, Christos G wrote:

> I just had some time open up on Wed., between 12:30-3PM.
>
> How about 2PM at the City Hall (is there a room available?) or we could meet for coffee at a place nearby.
>
> My office is about a 10-15 min walk from City Hall, CTPS is across the Green Line Boylston St Station and has several conference rooms, if we are lacking a meeting space.

*** That's good! Let me first see if we can get a room at City Hall at 2pm. If not, I would opt for the nearby coffee shop option (I know there are plenty) only because time is short and it would save the walk time from your office to my 3pm meeting. At some point, we probably need a longer meeting with a screen and board, but let's take advantage of what we have now.

I'll get back to you asap once I talk to our friends at the MONUM.

Christos

==========

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Wednesday, July 08, 2015 1:24 PM
To: Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
Subject: RE: INRIX data and capacities - explanation and times to meet

Hi Scott…

Thank you VERY MUCH for taking the time to describe the concept of capacity as you use it and, more generally, your modeling approach. This has been very helpful for me to read and to get a much better idea of what your thinking process is.

First, this clarifies how you define “capacity”. Sepideh and I had a meeting yesterday and we had pretty much reached the conclusion that you are viewing it as the “maximum number of vehicles that can travel past a single point”, that is, as a flow given a specific vehicle speed. We can work with that now that we understand it.

Second, I must agree with you that models for travel time as a function of demand have been “studied to death”. In fact, the BPR function and all other similar models you mention are all variants of a fundamental relationship from elementary queueing theory adapted to traffic systems. We have been using the “conical delay function” in our work for optimal traffic routing, but any other function would work just as well, so we are happy to go with whatever is commonly used in Boston or that you specifically recommend.

Once a delay function is selected, its exact shape depends on the values of certain parameters (such as the alpha, beta values you mention). For us, “capacity” is such a parameter and it normally captures the value at which a resource saturates. In traffic models, that’s the parameter value at which a road segment reaches the point where the function that gives vehicle speed as a function of demand takes on the value zero (i.e., a full jam). That’s why we have been seeking a constant value for “capacity”. But as I mentioned above, now that we understand things we can work with the notion of capacity you use.

I should point out that some of our work is model-independent, that is we aim to determine optimal routing decisions or optimal dynamic traffic light cycles without having to know specific delay functions or parameter values. This is made possible by the increasing availability of data (such as the INRIX data set) which is moving us towards data-driven methods rather than model-driven ones (as long as one has a structural model in place – like conservation of flow equations – but no detailed mathematical functions).

Also, I now understand why you use “period capacity factors” to “represent peak hour conditions within a period”. In a Monte Carlo type simulation of a traffic system, one would capture the fluctuations in traffic flows through random processes. But if you are not simulating at this level of detail, then what you describe attempts to capture reasonable average behavior.

About a meeting:

It turns out that I have to be at City Hall next Wednesday for a 3-4pm meeting with the Office of New Urban Mechanics and some DPW people. Depending on where you are located, I thought this might make it easier for you so that we could meet there earlier or at 4pm that day.

If that does not work (I don’t see Wed in your list of available dates), then Thurs or Fri next week works for me. If this is preferable, then how about Thurs at 1pm?

Regards,

Christos

****

* Christos G. Cassandras

* Distinguished Professor of Engineering

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* Head, Division of Systems Engineering, and

* Professor of Electrical and Computer Engineering

*

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Wednesday, July 08, 2015 9:48 AM
To: Pourazarm, Sepideh; Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately
Subject: INRIX data and capacities - explanation and times to meet

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our model is NOT to determine the roadway capacity. Instead, it is to approximate how travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate (area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again, our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could

also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

Mon 7/13 after 3PM

Tues 7/14 after 3PM

Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

The modeled (calculated) "Total roadway capacity for the period of time " means the capacity of roadway for all available lanes for time period AM (3hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the “capacity” (LOS F) of a road. In your email, you use the word “traffic jam”. This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don’t have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- "Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

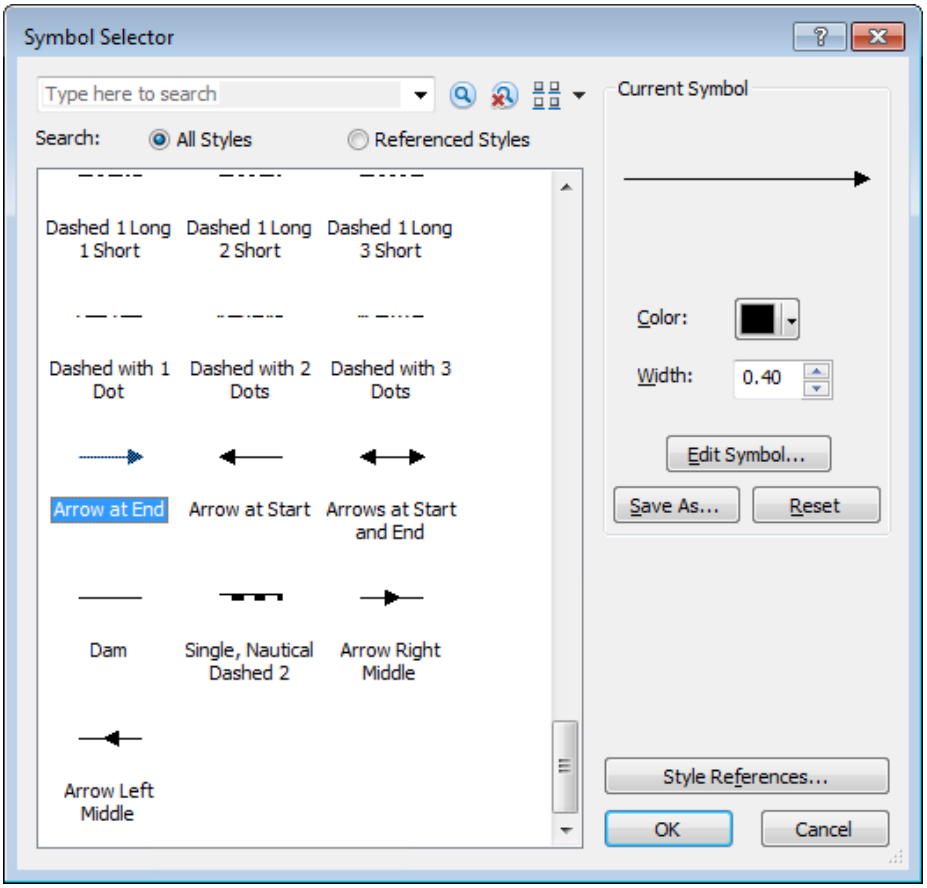
The time period definition in shape file

- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm
- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "

** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?

I wonder if you can explain what you mean by "at a level of surface of C".

> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.

**I think I have them in the attribute table as bellow:

SCEN_00_AB=AB_AM_Lanes

SCEN_00_BA=BA_AM_Lanes

SCEN_00_A1=AB_MD_Lanes

SCEN_00_B1=BA_MD_Lanes

SCEN_00_A2=AB_PM_Lanes

SCEN_00_B2=BA_PM_Lanes

SCEN_00_A3=AB_NT_Lanes

SCEN_00_B3=BA_NT_Lanes

Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.

I wonder if you can give me any idea how I should match capacity data with the INRIX

data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

--

Sepideh Pourazarm

PhD Candidate

Center for Information and Systems Engineering
Boston University
8 St. Mary's St.
Boston, MA 02215

On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we

just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

****

* Christos G. Cassandras

* Distinguished Professor of Engineering

*

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* Professor of Electrical and Computer Engineering

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2nd of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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<image001.png>

From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh
Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of great help to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
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>
> <image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM
To: Scott Peterson; Conor Gately; Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where

we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
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>
> <image001.png>

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Cassandras <cgc@bu.edu> Mon, Jul 13, 2015 at 5:59 PM
To: Scott Peterson <speterson@ctps.org>, "Pourazarm, Sepideh" <sepid@bu.edu>, Drashti Joshi <djoshi@ctps.org>

OK, we are set then!

Christos

==========

On 7/13/2015 5:34 PM, Scott Peterson wrote:

> Great, see you then!
>
> **Scott A. Peterson | Director of Technical Services**
>
> CENTRAL TRANSPORTATION PLANNING STAFF
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> CTPS MPO
>
> ---
>
> **From:** Cassandras [mailto:cgc@bu.edu]
> **Sent:** Monday, July 13, 2015 2:24 PM
> **To:** Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
> **Subject:** Re: INRIX data and capacities - explanation and times to meet
>
> Scott:
>
> I have secured a room for us to meet at City Hall 2-3pm on Wednesday. This is courtesy of Chris Osgood and Nigel Jacob. Let's meet at 2pm at the Mayor's Office on the 5th Floor of City Hall. Sepideh and I will be there, but just in case you arrive before us, please ask for either Chris or Nigel.
>
> Sepideh and I will have some ppt slides to set the stage so we can then discuss issues of model and data interpretation, seek answer to some more questions we have, and also look forward to some of our project goals and get feedback and suggestions from you.
>
> Regards, Christos
>
> ==========
>
> On 7/8/2015 3:44 PM, Cassandras, Christos G wrote:
>
> > I just had some time open up on Wed., between 12:30-3PM.

How about 2PM at the City Hall (is there a room available?) or we could meet for coffee at a place nearby.

My office is about a 10-15 min walk from City Hall, CTPS is across the Green Line Boylston St Station and has several conference rooms, if we are lacking a meeting space.

*** That's good! Let me first see if we can get a room at City Hall at 2pm. If not, I would opt for the nearby coffee shop option (I know there are plenty) only because time is short and it would save the walk time from your office to my 3pm meeting. At some point, we probably need a longer meeting with a screen and board, but let's take advantage of what we have now.

I'll get back to you asap once I talk to our friends at the MONUM.

Christos

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Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Wednesday, July 08, 2015 1:24 PM
To: Scott Peterson; Pourazarm, Sepideh; Drashti Joshi
Subject: RE: INRIX data and capacities - explanation and times to meet

Hi Scott…

Thank you VERY MUCH for taking the time to describe the concept of capacity as you use it and, more generally, your modeling approach. This has been very helpful for me to read and to get a much better idea of what your thinking process is.

First, this clarifies how you define “capacity”. Sepideh and I had a meeting yesterday and we had pretty much reached the conclusion that you are viewing it as the “maximum number of vehicles that can travel past a single point”, that is, as a flow given a specific vehicle speed. We can work with that now that we understand it.

Second, I must agree with you that models for travel time as a function of demand have been “studied to death”. In fact, the BPR function and all other similar models you mention are all variants of a fundamental relationship from elementary queueing theory adapted to traffic systems. We have been using the “conical delay function” in our work for optimal traffic routing, but any other function would work just as well, so we are happy to go with whatever is commonly used in Boston or that you specifically recommend.

Once a delay function is selected, its exact shape depends on the values of certain parameters (such as the alpha, beta values you mention). For us, “capacity” is such a parameter and it normally captures the value at which a resource saturates. In traffic models, that’s the parameter value at which a road segment reaches the point where the function that gives vehicle speed as a function of demand takes on the value zero (i.e., a full jam). That’s why we have been seeking a constant value for “capacity”. But as I mentioned above, now that we understand things we can work with the notion of capacity you use.

I should point out that some of our work is model-independent, that is we aim to determine optimal routing decisions or optimal dynamic traffic light cycles without having to know specific delay functions or parameter values. This is made possible by the increasing availability of data (such as the INRIX data set) which is moving us towards data-driven methods rather than model-driven ones (as long as one has a structural model in place – like conservation of flow equations – but no detailed mathematical functions).

Also, I now understand why you use “period capacity factors” to “represent peak hour conditions within a period”. In a Monte Carlo type simulation of a traffic system, one would capture the fluctuations in traffic flows through random processes. But if you are not simulating at this level of detail, then what you describe attempts to capture reasonable average behavior.

About a meeting:

It turns out that I have to be at City Hall next Wednesday for a 3-4pm meeting with the Office of New Urban Mechanics and some DPW people. Depending on where you are located, I thought this might make it easier for you so that we could meet there earlier or at 4pm that day.

If that does not work (I don’t see Wed in your list of available dates), then Thurs or Fri next week works for me. If this is preferable, then how about Thurs at 1pm?

Regards,

Christos

****
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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Wednesday, July 08, 2015 9:48 AM
To: Pourazarm, Sepideh; Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately
Subject: INRIX data and capacities - explanation and times to meet

Hello Christos / Sepideh,

Sorry for the long explanation, but I was trying to cover all of the questions that have been raised.

Hope this helps!

The Highway Capacity Manual (HCM) as previously referenced has an introductory chapter on capacity. Please take a look at that.

Basically, capacity is defined as the maximum number of vehicles that can travel past a single

point. For example, the speed flow curves in the HCM show that (with a safe spacing) and moving at an average speed of approximately 30 MPH, nearly 2300 vehicles per hour per lane can be accommodated. However as demand increases the speed begins to drop thus the optimum flow rate has started to decline. Further increases in demand will further reduce the speed and further reduce the flow rate.

Might I suggest we take the discussion away from capacity for a moment. The objective of the volume capacity ratio in our model is NOT to determine the roadway capacity. Instead, it is to approximate how travel time changes as a result of an increase in demand and is used to help simulate how drivers select paths in our roadway assignment process . The Bureau of Public Roads (BPR) function /curve was developed in the 1950s, and with some modifications, it is still used today. Basically the BPR curve was developed based on observations in the field. The authors of the curve measured how the speed changes as demand changes. So, in our model we are simply trying to establish the correct travel times as a result of increases in demand. This topic (in my opinion) has been study to death. You need only consult the Transportation Research Board web site and you will find dozens of papers over the last 20 years which address this. I would suggest you look at papers by Alan Horowitz in the 1990s and later. Alan's work shows how the BPR equations can be adjusted to use Level of Service (LOS E) capacity which represents the maximum flow which can be achieved on a facility. Alan's work also shows how the BPR curve can be adjusted to better represent flow on limited access and divided facilities.

However, the BPR curve is not the only game in town. Our software has pre-programmed volume delay functions as follows:

- BPR function with user defined alpha/beta values by facility type that can vary.
- Conical delay function.
- A combined conical and BPR function.
- A logit delay function.
- Akcelik delay function.
- A generalized cost function.

Also, we can write our own function to best fit the data. We have never tried to use the INRIX data to reverse engineer any of volume delay functions mentioned above.

So, if you want to try another function, we are certainly open to that. Some work better replicating speeds on freeways and others are better at arterials. You could also look at other ways to derive the link dependent variables used in the calculation. We use the volume over the practical capacity (LOS C). But, you could compute a different metric (such as LOS E capacity) based on additional road inventory data. For example, the capacity could be computed based on area type, land width, land use, shoulder width or availability, side frictions such as parking maneuvers, slope, intersection spacing, cross street traffic flow. We are open to your ideas, but a driver will usually search out a path in the network that provides safety and a minimal level of comfort, which usually is around LOS C and this is one of the reasons we start with this assumption.

Another topic which seems to be causing confusion is the period capacity. If the period is 3 hours long, then why not multiply the hourly capacity by 3? Here again, this goes back to traffic flow theory and what we are trying to do. Our goal is to approximate the average vehicle travel time during the time period, based on the BPR curve, and based on the alpha/beta coefficients we are using. If we were to multiple by 3, we would have to change our alpha/beta values. But this really isn't the answer. If you measure traffic flow during a 3 hour period, the volume is never constant, it fluctuates. So, if we plot the 15 minute variations in traffic volume over a 3 hour period and then calculate the area under the flow curve we would calculate that the area under the curve is approximately 80% of the total area. Our value of 2.5 was computed by examining these observed flow curves. Here again, this topic has been study a great deal and 2 things are clear. First, during any peak hour, a roadway cannot maintain a certain flow rate for the entire hour. At best, that flow rate

(area under the curve) approaches 1.0, but will not get any closer than 0.98. If we can never achieve a value of 1.0 for a single hour, then we certainly will never achieve that for 3 hours. So, here again, our objective is to approximate congested travel speed for all vehicles in the system for the 3 hour period.

Period capacity factors can be applied to represent peak hour conditions within a period (or an average of multiple hours within a period). This capacity factor performs a role that is analogous to the peak hour factor in the Highway Capacity Manual (where we want to know the peak 15 minutes within the one-hour analysis period). The factor is actually applied to the volume (and derived from the volume in practice; see the examples below). Remember that capacity constraint is a function of the volume-to-capacity ratio, so we're actually factoring the overall period volume (for three or five hours -- we'll use three here to simplify the numerical example below) down to peak hour volume so we can compare it to the standard hourly capacity The reason it shows up (numerically) as a capacity factor rather than a volume factor is computational efficiency: we multiply factor and capacity once at the beginning so we don't have to divide the volume twice (by factor and then by capacity) over and over again for every link during the assignment. The factors can be computed using the share of daily traffic counts in each hour, preferably computed from a sample of hourly traffic counts throughout a region (or perhaps from household survey data or any other source that might reveal daily traffic peaking).

For example, consider a three hour period with hourly shares of 6%, 8%, and 7% of total daily traffic.

A capacity factor that represents the peak hour could be estimated by dividing the sum of the three hourly shares by the peak hour share (e.g. (5%+8%+7%) / 8% = 2.5), which is what we use to define a peak period. A capacity factor that represents the average of the two highest hours in the period could also be estimated by dividing the sum of the three hourly shares by the average of the two highest shares (e.g. (6%+8%+7%) / ((8%+7%)/2) = 2.8).Notice that the values of the capacity factor will range from 1 (if all the traffic is in the one peak hour: (0%+21%+0%/21%=1) to 3 (number of hours in the period if all the hours are the same (7%+7%+7%)/7% = 3). If it's a five-hour period, the factor will naturally range from 1 to 5. In each case, the trip table itself will contain the number of total trips observed just in the period: that is, the capacity factor might be computed from shares of daily travel, but the trip table presented to the assignment will be (say) 6%+8%+7% = 21% times the total daily trips.

For advanced practitioners: In practice, the trip table for this time period within the day usually won't just be a uniform fraction of a total daily origin-destination table (e.g. 21% of all trips), but will be derived from a production-attraction (P/A) table based on using period-specific factors describing directionality for each P/A pair for each trip purpose during that period. Those period-specific factors will also be based on some kind of survey data. In a mid-day period, if P's and A's are equally distributed among origins and destinations, that might be the classic "transpose/add/divide-by-two" conversion, but for other time periods or trip purposes, "divide-by-two" might become a larger or smaller fraction in order to capture predominantly inbound or outbound flows during the period (though if you add up all the O/D trip tables for a full 24 hours, they will still add up to a balanced overall O/D table). Getting all the trip tables to add up right (and to respect constraints like "if you left by transit you will probably come home by transit") is one of the reasons that contemporary models are inclined to build tours first (rather than unlinked P/A trips), but they will still end up constructing directional period-specific O/D tables if they're going to do static capacity-constrained equilibrium assignment, and the capacity factor principles will still apply during assignment for multi-hour time periods.

I would be happy to come over sometime next week to discuss this with you and get an update on your research if you have time.

Options for me are:

Mon 7/13 after 3PM

Tues 7/14 after 3PM

Anytime on Thurs 7/16 or Friday 7/17

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 3:43 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Drashti.

Thus, the capacity per lane per hour for a particular roadway is constant during a day.

Best,

Sepideh

I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that

- This is because our Model time period capacity expansion factors are,

AM (3 hr)=2.5

MD (6 hr) =4.75

Pm (3 hr) =2.5

NT (12 hr) =7

These are adopted based on extensive research. For example,

Total Roadway Capacity for the AM time period = (capacity/lane/hr) * number of lanes*2.5 (capacity expansion factor)

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, July 02, 2015 2:08 PM
To: Drashti Joshi
Cc: Cassandras, Christos G; Conor Gately; Scott Peterson

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Drashti,

Thanks again for all your help. I really appreciate that.

1) for the capacity data the description is " Total roadway capacity for the period of time (AM,PM [3 hr], MD [6 hr] and NT[12 hr])". It seems that capacity of a road is a time-dependent variable. Would you please explain it?

- The roadway capacity is a function of highway functional class (CTPS functional class) and roadway geometry (median, controlled access, area type etc.).

The modeled (calculated) “Total roadway capacity for the period of time ” means the capacity of roadway for all available lanes for time period AM

(5hr).So the numbers you are looking at are the total number for time period and total number of lanes for each particular roadway.

*** I assume number of lanes, functional class and geometry of a particular road way are fixed parameters during a whole day. Thus, for a particular segment we should have:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 2 X AB_PMCAPAC

AB_NTCAPAC= 4 X AB_PMCAPAC.

However as I cross-checked the data, I see the following relationship:

AB_AMCAPAC= AB_PMCAPAC

AB_MDCAPAC= 1.9 X AB_PMCAPAC

AB_NTCAPAC= 2.8 X AB_PMCAPAC.

I wonder if you Could explain that.

2) Based on the definition above, AB_AMCAPAC=2682 means that the maximum flow capacity which can enter all lanes of the road segment in AM period (in terms of number of vehicle in **3** hours) is 2682. Is it correct?

3) In previous emails, Scott mentioned that this data is at "level of service of C" (showing a saturated road that is moving close to posted speed). Is it possible to provide us data at "level of service of E" (traffic jam)?

The following explanation is provided by our model development staff for questions 2 and 3.

- The AMCAPACITY = 2682 is the Level of Service (LOS) C capacity, not the ultimate or maximum capacity of the road. We use LOS C as this is the basis for the volume delay equations in our modeling process. So, no, 2682 would not be the maximum flow. Generally speaking this is approximately 75% to 80% of the maximum flow.

**Thanks for the explanation.

We have an aggregate travel model. Which means we look at things in terms of large time periods and how large groups of people move through the system. In this context, we simply simulate 4 time periods as you have seen. Consequently, the LOS C capacity is that capacity which research and field studies have shown is the best parameter for approximating how the volume to capacity ratio impacts congested speed. We do not calculate, nor do we have the data, to compute the maximum capacity or Level of Service F capacity.

**Thanks for the explanation. I actually need the maximum flow (capacity) in which the road is still not congested. Using Greenshield's traffic flow model f_{max}=(k_{jam}*v_f)/4 where k_{jam} is the jam density and v_f is free speed. Based on your explanation I think

the LOS C should be equivalent to the 75% to 80% of the same capacity.

Types of questions you are asking suggests a higher level of refinement than what we currently have in our modeling process.

For example, if you want to compute the “capacity” of a road segment or intersection (LOS F), then you should follow the procedures as outlined in the Highway Capacity Manual (HCM). These procedures are very detailed and require much more data than we can collect or use at a regional level. Using the HCM procedures is the one of the only ways to accurately calculate the “capacity” (LOS F) of a road. In your email, you use the word “traffic jam”. This is more of a colloquial term, not an engineering term. In the world of capacity, when demand exceeds capacity (LOS F), speeds fall below the optimum speed for processing and consequently vehicles become stopped.

We don’t have the tools or data within our modeling process to compute the maximum capacity (LOS F). That is not the intent of our process. If we were asked to compute the LOS F capacity, we would need to focus on a much smaller area of the network, and then we would compute the Level of Service F capacity based on the HCM procedures. The modeling process would then tell us the demand (traffic volume) on a segment, and then we could compare the volume to the capacity and determine the speed at which the traffic is moving through the area.

**Thanks for the explanation. I will talk to professor Cassandras and let you know if we really need the maximum capacity (LOS F) to be calculated. In order to approximate that can we assume

Maximum capacity=(LOS C Capacity)/0.75? If it is correct I think we can proceed with that for now.

Thank you very much,

Sepideh

I have more questions to ask (I will send some of them in another email). I wonder if we could meet in order to discuss them in details. We welcome you here at BU or we can come to CTPS.

Thanks again,

Sepideh

On Tue, Jun 30, 2015 at 12:09 PM, Drashti Joshi <djoshi@ctps.org> wrote:

Hello Sepideh,

Sorry for the delayed response, I was busy with other project priorities.

I have attached here two files.

- Attribute list" contains explanation of each attribute in the shape file.
- "CTPS funclass" includes roadway functional classification code and it's type.
- The "AB_AMCAPAC" means total roadway capacity for the period of AM (3hrs). Likewise for all other time periods.

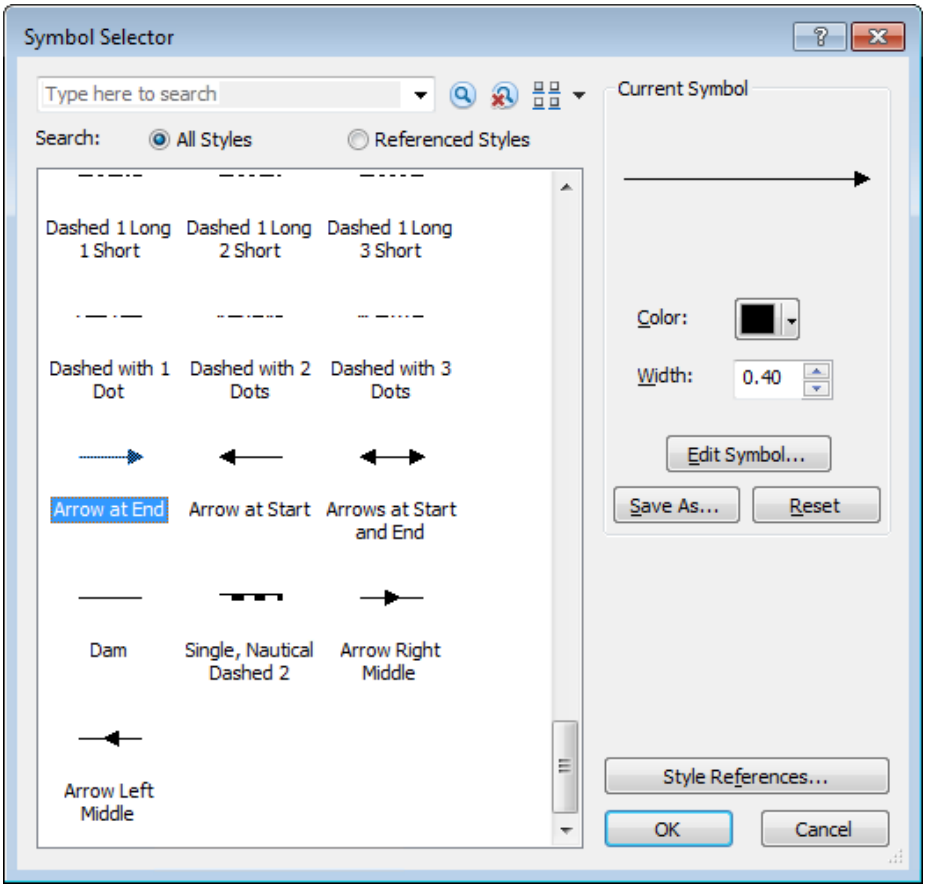
The time period definition in shape file

- AM = 6:00 am to 9:00 am
- MD = 9:00 am to 3:00 pm
- PM = 3:00 pm to 6:00 pm
- NT = 6:00 pm to 6:00 am

Directionality explanation (AB and BA)

The traffic volumes/number of lanes/capacities in the shape file are for the topological A to B direction and the topological B to A direction. The topological direction is based on how the line was originally draw when the linework was created. Thus the A to B, means the line was originally drawn as starting from point A and extending to point B. The topological direction is critical in the highway (or transit) network representation as it is used to define the volume direction.

To show the topological direction of lines (whether shapefiles or feature classes from geodatabases), open the symbol selection dialog for the layer in ArcMap (the fastest way to do this is to click directly on the layer's symbol in the table of contents pane), scroll to the bottom and select the "Arrow at End" symbol from the default ESRI symbol library.



It is also possible to show A->B characteristics (i.e. assigned volume or number of lanes) in symbols offset to the right side of the lines, and B->A characteristics in symbols offset to the left side of the lines.

Hope this helps.

Best,

Drashti

From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Thursday, June 25, 2015 3:18 PM
To: Scott Peterson
Cc: Drashti Joshi; Cassandras, Christos G; Conor Gately

Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Thanks Scott.

Best,

Sepideh

On Thu, Jun 25, 2015 at 3:11 PM, Scott Peterson <speterson@ctps.org> wrote:

Drashti will need to confirm that, but as an example a minor arterial will process about 800 vehicles per lane per hour. An interstate will process 2000 vehicles per lane per hour. Level of service describes how saturated the road is and LOC equal to C based on a scale of A to E would show a saturated road that is moving close to posted speed. A is free flow conditions and E is a traffic jam.

Sent from my iPhone

On Jun 25, 2015, at 2:44 PM, Sepideh Pourazarm <sepid@bu.edu> wrote:

> Thank you so much Scott.
>
> "CAPAC is the capacity, which should be defined as the capacity of 1 lane during 1 hour at a level of surface of C. "
>
> ** Then, AB_AMCAPAC=2682 means the maximum flow (in terms of number of vehicle per hour) which can enter one lane of a road segment in AM peak hours, is 2682 [#veh/hr] . Is it correct?
>
> I wonder if you can explain what you mean by "at a level of surface of C".
>
> I don't see one attribute that you will need and that is the number of lanes on each roadway. Drashti, could you confirm they have this.
>
> **I think I have them in the attribute table as bellow:
>
> SCEN_00_AB=AB_AM_Lanes
>
> SCEN_00_BA=BA_AM_Lanes
>
> SCEN_00_A1=AB_MD_Lanes
>
> SCEN_00_B1=BA_MD_Lanes
>
> SCEN_00_A2=AB_PM_Lanes
>
> SCEN_00_B2=BA_PM_Lanes
>
> SCEN_00_A3=AB_NT_Lanes
>
> SCEN_00_B3=BA_NT_Lanes
>
> Now, based on the meaning of terms AB,BA,MD,NT,AM,PM I can understand them.

I wonder if you can give me any idea how I should match capacity data with the INRIX data.

Thanks a lot,

Sepideh

Scott A. Peterson | Director of Technical Services

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From: Sepideh Pourazarm [mailto:sepid@bu.edu]
Sent: Wednesday, June 24, 2015 10:45 PM
To: Scott Peterson
Cc: Cassandras, Christos G; Conor Gately
Subject: Re: INRIX data and capacities - (2 of 2 e-mails)

Dear Scott,

Thanks for sending the data. I am trying to extract the capacity data in order to convert (INRIX) speed data to flow. I opened the shape file and its attribute table. I wonder if you could provide us a document to describe features in the attribute table of the road capacity map, e.g.

ANODE, BNODE, AB_AMCAPAC, BA_AMCAPAC, AB_MDCAPAC,

BA_MDCAPAC, AB_PMCAPAC, BA_PMCAPAC, AB_NTCAPAC, BA_NTCAPAC

I am also trying to match the new data with the INRIX data. In the latter the segments are identified by their "TMC" code. I didn't see similar coding in the attribute table of road capacity map. Based on my observation, street name and number are the only common features in both attribute tables. Would you please advise me about an efficient way to match both data ? I really appreciate your help.

Thanks in advance,

Sepideh

--

Sepideh Pourazarm

PhD Candidate

Center for Information and Systems Engineering
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8 St. Mary's St.
Boston, MA 02215

On Sun, Jun 21, 2015 at 4:02 PM, Cassandras, Christos G <cgc@bu.edu> wrote:

Thank you very much Scott!

We were able to open the files. It looks like the basic data are there and we just need some descriptions of the different features in it so that we can ultimately extract capacity info for the road segments as encoded in the INRIX data.

I have asked my student, Sepideh, to email you directly with specific questions. Conor, I am also cc'ing you in case you faced similar questions in your work.

Regards,

Christos

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* Christos G. Cassandras

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 5:01 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: RE: INRIX data and capacities - (2 of 2 e-mails)

2'"d of 2 e-mails with the GIS roadway network capacity data

Scott A. Peterson | Director of Technical Services

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From: Scott Peterson [mailto:speterson@ctps.org]
Sent: Thursday, June 18, 2015 4:58 PM
To: Cassandras, Christos G
Cc: Conor Gately; Pourazarm, Sepideh; Scott A. Peterson
Subject: INRIX data and capacities - (1 of 2 e-mails)

Hello,

I am attaching a zipped GIS shape file (3 files, 2 of which are included in this e-mail) containing our roadway network and capacities for the 2010 condition.

Let me know if you have any questions.

Regards,

Scott

Scott A. Peterson | Director of Technical Services

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From: Cassandras, Christos G [mailto:cgc@bu.edu]
Sent: Monday, June 15, 2015 11:40 AM
To: Scott Peterson
Cc: Conor Gately; Pourazarm, Sepideh
Subject: Re: Sharing INRIX data with SCOPE partners

That's great Scott! Even if it does not line up perfectly it will be of

great help to us.

Regards,

Christos

Sent from my iPhone

Christos G. Cassandras

Distinguished Professor of Engineering

Head, Division of Systems Engineering

Boston University

On Jun 15, 2015, at 4:28 PM, "Scott Peterson" <speterson@ctps.org> wrote:

> Hello Christos,
>
> We do have a roadway network layer in GIS that has capacities. I will have someone send it to you this week.
>
> It may not line up perfectly with the INRIX GIS layer, but someone should be able to snap it to the roadway network that has capacities.
>
> It may end up being a many to one relation, given the coarseness of the INRIX segments.
>
> Regards,
>
> Scott
>
> **Scott A. Peterson | Director of Technical Services**
>
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>
> <image001.png>

From: Christos G. Cassandras [mailto:cgc@bu.edu]
Sent: Friday, June 12, 2015 6:13 PM

To: Scott Peterson, Conor Gately, Sepideh Pourazarm
Subject: Re: Sharing INRIX data with SCOPE partners

Hi Scott...

I wanted to give you an update on our work with the INRIX data and seek your advice and help.

First, we have made great progress with the data to the point where we can project it on maps of the Boston area and get some good insights. Our current challenge is to extract from the raw data (which are vehicle speeds at specific roadway segments at specific times) the kind of information that we need to drive simulators for the Boston area traffic and to infer traffic flows which give us the ability to estimate and predict congestion.

What would be helpful is if you have any data or can point us to anyone who does regarding CAPACITIES of different road segments, that is, numbers of vehicles that can "fit" into such a segment. Is there any dataset that provides such information in some form? It doesn't have to be in terms of vehicle numbers, but maybe physical dimensions from which we can extract what we need.

Any thoughts or pointers on that?

Many thanks,

Christos

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On 4/23/2015 10:35 AM, Scott Peterson wrote:

> Hello Christos,
>
> I heard back from Pete and it is fine to share the 2012 Inrix data with you, see response below.
>
> I'll let Conor get you access to the data sets that you need.
>
> If you have questions, please let me know and please keep me posted on your progress.
>
> Regards,
>
> Scott

Scott A. Peterson | Director of Technical Services

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