An Identification and GIS Representation Standard for Road Networks to Support Planning and Research, Version 2.1

Proposed by: David P. Racca, Center for Applied Demography and Survey Research
University of Delaware, dracca@udel.edu

Introduction

Over many years a suitable road network representation for use in GIS has been needed for transportation research and planning. A number of representations have been used including the DelDOT Centerline File, Tiger Line Files, County Centerline files, TeleAtlas, the DelDOT Cartographic Maps, and road networks used by the Highway Performance Modeling System and the Delaware Travel Demand Forecasting Model. These products have been used as basemap layers, for address matching, for routing, and/or for locating transportation facilities. They each are created from different line sets and contain features that are useful for the uses they were designed for. Through a project conducted by CADSR and the DelDOT Division of Planning it has been made clear that a transportation network representation is needed that can be used to reference traffic count, traffic impact study (TIS), and other travel data. Also a standard identification system for transportation features was desired that could exist outside of a particular road centerline in use. As traffic count, TIS, GPS and other traffic data are compiled in databases, a GIS transportation network layer was needed that could display the traffic data and relate it to a number of other transportation data resources. What is described is first and foremost an identification standard. A centerline product was created embodying this standard as were a number of supportive resources to implement it. While this centerline was based on the DelDOT Centerline, any centerline product that incorporates the Delaware Linear Referencing System could be used by various users to reference transportation data. The LRS and the standard together form a powerful method of transferring information between various representations and form a meaningful identification system tied to an existing standard. The developing specifications used to create a standard road network referred to here as the “Delaware Linear Referencing System (DELRS) Centerline” are described here.

Needs and Desired Features

In developing the DELRS Centerline the following needs and features were targeted:

- Incorporation and conformance to DelDOT standards and existing methods of locating transportation data
- Not limited to a particular geometry or road segmentation scheme
- The ability to reference and display information about traffic data including traffic counts and GPS data. Required is a facility to deal with data about turns.
- Effective management of impedance and routing data
- Manageable and clear methods of update and maintenance over time as new roads are added and geometries change.
- Inclusion of all travel ways large and small
- Effective display and referencing of information related to turns and travel flow directions on roads.
The Delaware Linear Referencing System (DELRS)

For all roads that DelDOT maintains, a route identifier (rdwayID) is assigned to groups of contiguous road segments which are assigned official mile points based on the road inventory from beginning to end. The location of “point events”, like the location of a sign or an accident, are specified by a particular route and mile point. A section of road, and a portion of a pavement being rehabilitated, are “linear events” and are specified by a particular route and a beginning and end mile points. The DELRS has been in use for over 20 years and has many advantages as a basis for an identification system:

- It is used to reference all data in the DelDOT road inventory and in several other transportation data sets. It is an existing standard and is an uncomplicated system.
- GIS features can exist as point and linear event tables rather than as GIS cartographic features. This allows data to be represented outside of a particular cartographic representation. Road network features can be described independent of geometry.
- It supports dynamic segmentation, use of data without regards to road network segmentation in the base GIS model.
- Supports tabular analysis and manipulation of information in addition to geometric analysis.
- As described below it can produce an identification system that integrates references to various transportation entities (intersections, travel ways, turns).
- Roads are linear features and what is of interest is typically features along the path. Linear referencing systems have an advantage.

The DELRS allows for a consistent and integrated method of identifying transportation features and travel movements and forms the basis for the proposed standard. Other alternatives were considered but because of the reasons above and as further outlined, the decision was made to base the identification on the DELRS.

* One method would be to use some kind of geographic coordinate based identifier. The identifier would be some type of “geopin”. This might be useful in that features could be more easily spatially searched and indexed. Knowing the identifier would tell you where the road was, for instance. A road though is not a point in space but is represented as a string of coordinates. There were many problematic questions for a coordinate based approach. Would the spatial extent of the road segment be used? Beginning and end coordinates? The midpoint? How would it not be confused with other road segments? Would an identifier based on coordinates then tie the identifier to a particular geometric representation of the road segment? The coordinate approach would seem more feasible for a collection of discreet point locations. There may be a clever coordinate based method but how such an approach could be implemented or be useful for a series of interconnected paths wasn’t at all clear. Another approach would be to just assign unique, somewhat arbitrary identifiers. That is how centerline features are referenced in most representations (e.g. “dynamapID” with TeleAtlas). Someone keeps the list of valid numbers and is in charge of assigning new ones and while they don’t have a particular meaning they are the standard. The RDWAYID used in the DELRS for route naming is basically just that, and there would seem to be no advantage in defining another set of numbers to assign and maintain. Perhaps there is a clever alphanumeric identification system that could possibly employ coordinate locations as well but nothing could be found that would seem to have any advantage over a LRS approach.
Transportation Features That Are Identified In The DELRS Identification System and Centerline

Managing traffic count data and other information about the transportation network requires some basic transportation entities:

- **Road Segments** – portions of the roadway, typically delineated between two intersections (but not necessarily). In centerline products typically the road is represented as one line. Traffic data is almost always associated with a particular flow direction on the road so for a given portion of road there are two identifiers, one for each direction of flow.
- **Intersections** – Any point where road segments meet.
- **Approaches** - An approach is the portion of the roadway abutting the intersection that is affected by the characteristics of the intersection. Traffic count and traffic impact study data describe the intersection under study as made up of approaches and data is associated with the approach. The idea of an approach is also useful for accident analysis where the safety characteristics of a roadway are considered to be influenced by the proximity to the intersection.
- **Movements** – these are “turns” that include right turns, left turns, thru (as in proceeding straight thru an intersection), and U turns. Traffic counts are associated with turning movements in time. Impedances (time costs) are associated with turns in routing applications.
- **Site or Points** - Transportation data that can be referenced by route and mile point locations. The location of a transportation facility or entity (like location of traffic impact study) is a linear referencing point event.
- **Lanes/Lane Groups** – At this stage Lanes in a roadway would be the “children” of road segments and movements (right/left/thru movements) and are currently numbered and associated with road segment identifiers and movement identifiers when capturing TIS data about lanes. At this stage a standard for managing lane identifiers has not been fully addressed though it is believed that the standard described here could be extended to accommodate this level of detail within movements.
- **Turn Tables** – Turn tables manage the impedance of segments and movements within the road network representation.

Comments about Lanes/Lane Groups above speak to the scale of this proposed standard. The basic transportation entities that would be used at a planning level are the focus. For instance, typically at a planning level the total traffic flows or level of service of a particular movement are more of interest, where details of the functioning of lanes within the movement is in the realm of micro simulation and detailed traffic analysis and engineering. This standard and the support of capabilities in archiving of traffic data at this planning level can certainly aid the traffic analyst or engineer though.

The following pages summarize the identification system for the above entities.
Identification of Road Segments

Beginning with road segments, please refer to the figure below showing Sudlers Row. The route is RDWAYID = 616 and is made up of one segment that begins at mile point = 0 and ends at mile point = 1.76.

There are two identifiers associated with the segment, one for the direction of flow corresponding to the direction of the mile pointing and one for the direction of flow in the reverse direction. The name of the identifier is LRSID and is formatted as a 16 character string variable. The first six places are reserved for RDWAYID (RDWAYID’s go into the 100,000’s), the next 5 places are kept for the beginning mile point, and the next 5 places are assigned to the end mile point. Mile point values are kept to the 1000th of a mile so in this example milepoint 1.76 is stored as “01760” in the LRSID. Each direction of the road is symbolized with the red arrows and is identified as shown below.

\[
\text{LRSID} = \text{RDWAYID} + \text{BEGMP} + \text{ENDMP}
\]

i.e. “000616-00000-01760 “

OR (in opposite direction from mile pointing direction)

\[
\text{LRSID} = \text{RDWAYID} + \text{ENDMP} + \text{BEGMP}
\]

i.e. “000616-01760-00000 “
Identification of Movements

Movements are defined as the change from one portion of road to another at an intersection. Movements are turns and are the GIS entities tied to information about turns such as a traffic count or turn impedance. The identifiers for movements can easily be specified with inspection of routes and mile points of intersecting segments. The movement identifier is built from the type of turn Right (R), Left(L), Straight or Thru(S) and the origin segment. To reference a typical traffic count or traffic impact study data file, only the approach LRSIDs are needed to generate the movement LRSIDs. The example below shows an example of how this works. The movement LRSID provides an easy extension of the LRSID for segments. In practice this has worked very well.

Movement LRS

<table>
<thead>
<tr>
<th>Movement Description</th>
<th>LRSID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northbound Alley Mill to Clayton Delaney, Right Turn</td>
<td>0001200133001400R</td>
</tr>
<tr>
<td>Northbound Alley Mill to Alley, Thru</td>
<td>0001200133001400S</td>
</tr>
<tr>
<td>Northbound Alley Mill to Clayton Delaney, Left Turn</td>
<td>0001200133001400L</td>
</tr>
<tr>
<td>Southbound Alley Mill to Clayton Delaney, Right Turn</td>
<td>0001200140001580R</td>
</tr>
<tr>
<td>Southbound Alley Mill to Alley, Thru</td>
<td>0001200140001580S</td>
</tr>
<tr>
<td>Southbound Alley Mill to Clayton Delaney, Left Turn</td>
<td>0001200140001580L</td>
</tr>
<tr>
<td>Eastbound Clayton Delaney to同盟 Mill, Right Turn</td>
<td>0005320232003400R</td>
</tr>
<tr>
<td>Eastbound Clayton Delaney to Clayton Delaney, Thru</td>
<td>0005320232003400S</td>
</tr>
<tr>
<td>Eastbound Clayton Delaney to同盟 Mill, Left Turn</td>
<td>000532050002820L</td>
</tr>
<tr>
<td>Westbound Clayton Delaney to同盟 Mill, Right Turn</td>
<td>000532050002820R</td>
</tr>
<tr>
<td>Westbound Clayton Delaney to Clayton Delaney, Thru</td>
<td>000532050002820S</td>
</tr>
</tbody>
</table>
Identification of intersections and points in the road network

Locational reference of intersections in the DelDOT intersection file includes route and mile point values based on the Delaware LRS. Intersections are linear referencing point events. The identification method of referencing points on the road network are the same. So the identification scheme is not really different. It is the RDWAYID with the mile point.

LRSID = RDWAYID + mile point

In this example there could be two LRSIDs for the intersection, “00012001400” or “00053202820”. The formatting of the LRSID is the same as all other entities, it is a string field with the first six characters specifying the RDWAYID and the next 5 reserved for the mile point. If the intersection was comprised of 3 segments coming together each having different RDWAYIDs there would be 3 valid LRSIDs. With 4 segments there could be 4 valid LRSIDs. The same kind of situation exists if intersections are specified by road name. Intersection master tables would include all valid LRSID and all RDWAYID’s and mile points, and all road names as they do now at DelDOT.

Locating information by intersection is a common need. Typically intersections are referenced by their road names and there can be various specifications of an intersection. When one considers also that a particular road is often referred to with different names such as “Kirkwood Highway” and its State route, “Route 2”, there is a need for cross reference tables and name alias tables. Identification of intersections by road name in this standard is only covered to the extent that road names should be included in master intersection tables. Development of road name alias tables is considered to be more in the realm of address standards and programming considerations when dealing with various ways users will name a road.
Identification of Approaches

An approach is seen as a portion of the roadway that is affected by the characteristics of the intersection. Sudlers row is shown again below. The red arrows represent the approaches to each intersection properly oriented on the right side of the road.

Approaches are handled two ways. First as with movements the link lrsid can be used with a suffix, “A” in this case. So the west bound approach for Sudlers Row would be 000616 01760 00000A” (spaces added for clarity). In applications the approach, the area that is in the influence of the coming intersection is delineated in different ways with different segment lengths. For instance, accidents within the approach of an intersection were being analyzed, the approach could extend well back from the intersection and would be different from intersection to intersection. An identifier that would capture the actual segment of a specific approach is derived by using the route and directional mile points just as with the LRSID for a segment. So for instance for the west bound approach, the 100 feet preceding the intersection might be defined as the approach. Where 0.01 mile = 52 feet, the beginning mile point of the approach would be 0.02 and the end mile point would be 0 so the approach would be specified as “000616 00020 00000” and for the east bound approach “000616 01740 01760”.
GIS Graphic Transportation Features to Support Identification and Display

Various transportation software often include utilities within the software to display travel directions in a clear manner. Through this discussion figures have included graphic arrows to show approaches, travel direction, and movements (in red or green) and are screen shots of actual GIS layers. These cartographic layers for movements and travel direction are very much needed to display data tied to those paths or turns. For example, a simple centerline segment is not as flexible. Cartographic layers as show in the figure below clearly specify the direction of the traffic count on the centerline file. So if traffic counts exist for each direction on roadways, as below, they can be clearly displayed. The
numbers displayed could be a volume, capacity, safety index, or whatever information that could be associated with that travel direction.

Furthermore cartographic movement layers provide a GIS graphic feature to reference and display the linked tabular data. Typically for instance turn impedance is kept in turn tables where the “from” and “to” roads are listed in columns with impedance values. A turn often only exists in GIS as such a table and is not displayed unless features allow for it in the transportation software. Some software may handle the display of data without a corresponding graphic feature but the goal in creating a standard included the ability to manage and map data in any basic GIS and basic GIS needs a feature to attach data.

Just as important, having graphic features for movements and travel ways allows user friendly interaction with the identification system. To capture an identifier (LRSID) the user simply needs to display the area of interest and graphically select the particular movement or travel way and the identifier can be captured so that it is not necessary to type the identifier, avoiding errors and difficulty when identifiers are more complex.

The graphic GIS layers for movements, approaches, and travel ways were all generated programmatically on the DelDOT Centerline file. They were not hand drawn and can be regenerated at any time and further customization is possible. Some refinement in programs continues so as to achieve the most graphically clear representations particularly in densely populated areas. These programs can be applied to any centerline product that incorporates the Delaware LRS. (For more information on programs to support this standard, contact the author.)
Database Field/Column Formats

There are only a few specifications for columns included here.

**RDWAYID**
Positive Integer Less than 1,000,000, converted to a 6 character string in LRSID’s
All other route fields that specify routes are formatted the same as RDWAYID.
“0”s are used to hold the places not used, for instance, if a RDWAYID is 2853, the mile point is stored as 002853 when converted to a string.

**Mile Point Fields**
5 place decimal numeric, XX.XXX, converted to a 5 character string in LRSID’s.
All fields holding mile point data are formatted in this way.
“0”s are used to hold the places not used, for instance, if a mile point is 1.83, the mile point is stored as 01830 when converted to a string.

**LRSID**
String/Text between 11 and up to 20 characters
Intersection LRSID is 11 characters
Road Segment LRSID is 16 characters
Approach LRSID is 16 characters
Movement Identifiers go up to 17 characters

Implementation of the DELRS Standard: A DELRS Centerline File

Establishing a standard identification system was a necessary step in developing methods of archiving traffic count and traffic impact study data. An implementation of the standard using the DelDOT Centerline as a foundation was necessary to begin the work of capturing travel data. This process is briefly described below as it relates to the functionality of the identification standard. Plans are to continually refine the DELRS Centerline File that resulted.

**Centerline Preparation**

For a more complete product with less errors, there were some preparation steps necessary to take when using the DelDOT Centerline file:

- Route identifiers (RDWAYID) are not available for all roads in the DelDOT Centerline File. In some cases where DelDOT has no responsibility for maintenance of a road a route and mile point is not available. Route ID’s and mile points had to be generated for these or left out of the implementation.
- Over the years some major roads have been depicted in centerline files as dual lane highways. A center line is maintained for both directions and appears as a dual lane highway graphically. This works very well for access restricted highways like Interstate 95, but for other roads (Concord Pike) where the lanes do allow left turns at many spots and are not physically separated by a considerable distance this causes an inconvenient and unnecessary complication when
displaying traffic turning movements. Even when there are barriers (medians) where turning is restricted, the barriers do not completely separate the two lanes. A situation occurs where at an intersection double lines cross a single centerline (or sometimes double lines over double lines) and this creates a problem as to where to specify the intersection and other geometric difficulties as well as how to attach and display traffic data. This is seen as a mixture of two different scales, one a road centerline scale more suitable for planning, and another scale that captures lane geometry. Certainly TIS data references lanes and lane counts but for the targeted level of planning and study of traffic flow and impedances, capturing all lane geometries in a state wide GIS file is a very large task. The product described here does not address the needs of micro simulation. So highways that were depicted as dual lines, except for restricted access highways, were edited and represented by one centerline.

- Prior to processing the centerline is the time to do any updates on new roads.
- There were some general clean up steps done before processing, though most were left to be cleaned by programming.

**Computer Programs to Generate the DELRS Centerline**

Road centerline files are always in need of maintenance and update. A primary goal was to create a centerline file in conformance with the standard that could be regenerated at any time from the source materials. In fact what was created was a program that could take any centerline file that conformed to the Delaware LRS and clean the file, create standard identifiers, and create the set of integrated layers that included the identification system as well as references to the original source data. Those layers created by the programs are:

- DELRS Centerline
- Intersection File
- GIS Cartographic and Reference Layer for Movements, Approaches, and Travel Direction
- Turn tables – turn tables

The programs were written in ARCINFO AML that is available to the University of Delaware, Delaware State and local agencies, and is included in full versions of ARCMAP (ARC Workstation) by ESRI. Programs could be translated to other languages. Products were created in ESRI formats. The data though is transferable and usable to any GIS system, even to an extent for software that does not support linear referencing.

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*AML is an older programming but in the opinion of the author allows for a great deal of control and clarity while programming and is more of a higher level batch language for GIS than Visual Basic for Applications (VBA) for instance. AML seems to be particularly useful for cleaning and processes that address nodes and segmentation in GIS files. But, perhaps the choice of programming language may be a preference based on the experience of the author. Perhaps if update was very frequent the processing would be done in another language.*
Routes

Routes are paths built on transportation travel ways. They are built from collections of road segments and characterized by the data associated with those segments as well as the data associated with movements from segment to segment. Routes are a higher level entity. Currently a route is specified in a database as a list of links. Larger segments within a route can be specified as linear route events by rdwayid and beginning and end milepoint.

Application to Routing and GPS Data

Finding a minimum or optimum path, or resources within a particular distance or travel time of destinations as calculated in routing applications depends on a management of impedance. Impedance, the costs of travel, whether in terms of time or distance, is data that is tied to the road segments and movements/turns. Impedance, like the number of seconds it takes to travel a portion of road or the number of expected seconds it would take to make a right turn, is data that can be associated with the entities of the GIS road network model and can be managed and displayed, just like data for traffic volume or capacity. So this standard is very relevant to the management of routing data. Impedance data for turns is data about movements. Field data concerning volumes and travel times for movements can be used to develop impedance values for more detailed routing applications that can rely on historic data. In particular, GPS data can be aggregated and referenced to segments and movements to develop travel speed profiles and archives. An identification system as proposed is needed for that.

Benefits of the Linear Referencing System Approach

As mentioned the DelDOT LRS is a long time standard that assigns route and mile point identifiers that are maintained by DelDOT. There are also some other apparent benefits. As part of the processing, the particular segmentation scheme of a road centerline being processed is captured as linear LRS events. If one has a centerline with the DelDOT LRS and a GIS that includes GIS support for linear referencing and where some other centerline file is available that also includes route and mile point references in conformance to the DelDOT LRS, it is fairly straightforward to map all attributes and segmentation schemes between the two. There are a few road centerline files in use in Delaware. Where the DelDOT LRS was incorporated in any one of them, attributes and data whether it was data such as address ranges, point incidents, or impedances, could be transferred relatively easily. This is conflation using the LRS rather than a spatial conflation based on geometry and segmentation of various line sets. This is aligned with goals to create a standard for referencing transportation that was independent of a particular geometry of a road centerline file. Two road centerline files with different line sets could each be in conformance to standards. Information referenced along the roadway from two sources could also be related by processing tabular information of the linear referencing ranges.
Traffic Count Data Sample

Below is an example based on the traffic count table below. The input procedure would be to copy and paste the approaches from the GIS map for the various directions into the header traffic count data file and then the process would generate turn-count records for motions (Right, Thru, Left) for all times as shown at the bottom of the page for 7:00AM.

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Irons From N</th>
<th>Holts From E</th>
<th>Irons From S</th>
<th>Holts From W</th>
</tr>
</thead>
<tbody>
<tr>
<td>07:00 AM</td>
<td>12 R 21 T 3 L</td>
<td>0 5 2 R 2 9 3</td>
<td>0 3 4</td>
<td></td>
</tr>
<tr>
<td>07:15 AM</td>
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<td>1 7 2</td>
<td>0 5 5</td>
<td></td>
</tr>
<tr>
<td>07:30 AM</td>
<td>5 15 1 T 2 6 4</td>
<td>1 18 2</td>
<td>3 3 6</td>
<td></td>
</tr>
<tr>
<td>07:45 AM</td>
<td>7 14 3 T 2 5 2</td>
<td>0 16 1</td>
<td>3 1 5</td>
<td></td>
</tr>
</tbody>
</table>

Translation To Database Records for the 7:00AM Interval

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>MoveID</th>
<th>Count</th>
<th>FromRoad</th>
<th>ToRoad</th>
</tr>
</thead>
<tbody>
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<td>07:00AM</td>
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<td>Irons FN</td>
<td>Holt</td>
</tr>
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<td>21</td>
<td>Irons FN</td>
<td>Irons</td>
</tr>
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<td>1/21/2009</td>
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<td>3</td>
<td>Irons FN</td>
<td>Holt</td>
</tr>
<tr>
<td>1/21/2009</td>
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<td>001288 02480 01860R</td>
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<td>Holt FE</td>
<td>Irons</td>
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<tr>
<td>1/21/2009</td>
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<td>001288 02480 01860S</td>
<td>5</td>
<td>Holt FE</td>
<td>Holt</td>
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<td>1/21/2009</td>
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<td>001288 02480 01860L</td>
<td>2</td>
<td>Holt FE</td>
<td>Irons</td>
</tr>
<tr>
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<tr>
<td>1/21/2009</td>
<td>07:00AM</td>
<td>001288 01170 01860L</td>
<td>4</td>
<td>Holt FW</td>
<td>Irons</td>
</tr>
</tbody>
</table>
Future Plans

Through capture and archive of traffic count and TIS data the standard is being further tested and developed. The Delaware Linear Referencing Centerline, and the data tables and cartographic movement layers, and the processing programs that are used to create and maintain the file, will continue to be developed as resources allow. The goal is an established standard and an embodiment of the standard in a GIS road network model that can be used for transportation planning and research. The identification standard depends on the Delaware Linear Referencing System but given that, a standard identification can be achieved outside of any particular GIS representation or software and is a system that can be understood by users who want to reference or search transportation data.

Further update and preparation of the DelDOT Centerline file will be needed. Refinement of programs for creation of the cartographic GIS layers for approaches and movements is needed. The further development of programs that use the standard to capture and archive transportation data such as traffic counts and GPS data could support many applications.

One note to close on is that a “perfect” source centerline file and perfectly developed DELRS Centerline with related products is not necessary to make progress once there is a standard in place for how data will be referenced. There will always be refinements and updates. A statewide routable DELRS Centerline file has been built and is being used to reference archived data for traffic volume, speed, capacity, and travel time, and is performing nicely with mapping interfaces and database queries.