TMG 2022 EMME NETWORK CODING STANDARD

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TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION

This report documents the 2022 Emme Network Coding Standard (NCS22)[1] as developed by the Travel Modelling Group (TMG) and its partners.[2] This is an update of the 2016 coding standard (NCS16), which has been the basis for all Emme-based network modelling undertaken by TMG over the past five years. The intent is that NCS22 will be the standard for all network development work moving forward by all participating agencies.

The importance of a common network coding standard for regional travel demand modelling cannot be overstated. Without a common coding standard, networks cannot be transferred or compared from one agency to another and common network modelling procedures (assignment modules, etc.) cannot be developed.

Several criteria provide the basis for development of this coding standard:

- Maintaining wherever possible consistency with previous standards/conventions so as to minimize the need to recode legacy networks to the new standard. Limits obviously exist in terms of enforcing this criterion, since a number of extensions of /changes to NCS16 and other legacy standards are required to properly support current regional modelling efforts and practice.
- The standard should be complete in that it addresses all elements of network coding.
- The standard should provide flexibility to meet individual agency needs, providing that this flexibility does not compromise the basic commonality of regional networks for travel demand modelling purposes.
- The standard should avoid assumptions that reflect model design (e.g., how to account for truck movements and their effect on lane capacities) rather than network "base data".
- Harmonizing as much as possible coding conventions used in GTAModel and GGH Model (GGHM).

Sections 3, 4 and 5 of this report deal with each of the three primary network building blocks: nodes, links and transit lines, respectively. Prior to discussion of these components, Section 2 defines the units of measurement used within the standard.

2 UNITS OF MEASUREMENT

2.1 UNITS

Metric units are used throughout NCS22. Table 2.1 defines the standard units of measurement used.

[1] TMG policy is to update the NCS in TTS years so that the most recent conventions can be used when updating travel demand modelling systems with the most recent TTS data. Due to the COVID-19 pandemic, the TTS that normally would have been conducted in the fall of 2021 has been deferred to the fall of 2022.

[2] TMG partners involved in developing this coding standard are: Metrolinx, Ontario Ministry of Transportation, the Cities of Toronto, Hamilton, Mississauga, Brampton and Vaughan, the Regional Municipalities of Halton, Peel, York and Durham and the Toronto Transit Commission.

Table 2.1 Units of Measurement

Measure	Unit
x,y coordinates	metres
Length	kilometres
Time	minutes
Speed	km/hr
Cost/fare	$
Energy	MJ

2.2 COORDINATE SYSTEM & PROJECTION

The coordinate system used is the Universal Transverse Mercator (UTM) 6 Degree System. The origin point of the reference grid is 4,000 km north of the equator and 500 km west of longitude 81 degrees west. The vertical axis is parallel to the true north at longitude 81 degrees west. All units are in metres.

To maintain historical consistency, a fixed projection datum for the spatial reference database should be used. Since 2001 networks have been encoded using the NAD 83 projection. This continues to be the standard in NCS22. Previous years' Emme networks hosted by the DMG prior to TMG taking over base network development in 2011, however, were developed in the NAD 27 projection. Spatial references historically used are provided in Table 2.2.

All network X-Y coordinates should use the full set of UTM digits to facilitate interchanging Emme and GIS files.

Table 2.2 Spatial References for Selected GTHA Networks & Traffic Zone Boundaries

Application	Datum
TMG 1986, 1991, 1996	NAD 27
TMG 2001, 2006, 2011, 2016	NAD 83
TMG 2019, 2020	NAD 83
Pre-2001 Emme/2 Networks	NAD 27
2001 Emme/2 Network	NAD 83
1991 GTA Traffic Zone Boundaries	NAD 27
1996 GTA Traffic Zone Boundaries	NAD 27 and NAD 83
2001 GTA Traffic Zone Boundaries	NAD 83
2006 GTA Traffic Zone Boundaries	NAD 83

3 NODES

Four major classes of nodes exist in any regional network model:

- Zone centroids for traffic zones that are internal to the region being modelled (*internal zones*).
- Centroids for *external zones* and/or *gateways* representing the interconnections between the region being modelled (e.g., the GTHA or the GGH) and the areas surrounding the region. These external centroids are required so that trips between these external areas and the internal study region can be modelled, usually using more simplified methods than used to model internal travel within the study region.
- *Station centroids*, which represent exclusive right-of-way (EROW) stations (for rail, BRT or any other EROW transit service) as destinations/origins for access/egress trips to/from these stations by non-EROW transit and/or non-transit modes (auto access to rail; transit/walk access/egress to/from rail; etc.). These station centroids are required so that Emme can assign access/egress trips to/from these stations and are essential for all stations that have park & ride facilities. This station centroid concept can be extended to include stand-alone park & ride lots, etc. that define other types of transfer points (e.g., from SOV to HOV travel) for which a "trip segment" may need to be explicitly assigned in the network..
- *Regular road and transit nodes*, which are the basic building blocks of the road and transit networks since they define the end points of the links within these networks.

In order to do certain forms of transit assignment a hypernetwork is sometimes generated (TMG, 2015). The hypernetwork consists of regular road and transit nodes, but is labelled separately (Table 3.2). The labelling generally occurs automatically during hypernetwork generation.[3]

Sections 3.1 and 3.2 define centroid and regular node numbering conventions, respectively. Section 3.3 discusses node attributes.

3.1 CENTROID NUMBERS

Zone systems are increasingly difficult to standardize due to the desire of individual agencies to custom-design their zone system for their particular needs. Also given the flexibility of modelling software to accommodate a variety of (well-defined) zone systems, it is unclear that a standard zone system is essential for regional network modelling, providing that the following criteria are met:

- Clear, systematic, mutually exclusive ranges for centroid numbering are maintained for internal zones, external zones/gateways and station centroids, respectively. In addition, systematic, mutually exclusive numbering ranges must also be maintained for each regional municipality / county within the internal study area. These ranges should be clearly defined for each zone system used.
- The mapping of each zone system to standard regional aggregate zone systems is specified. At a minimum, these should include mappings to regional municipalities and

[3] See, for example, the TMG hypernetwork generation procedure used in GTAModel V4 (https://tmg.utoronto.ca/doc/1.6/gtamodel/index.html).

TTS planning districts. To facilitate common modelling procedures, Emme zone ensemble **gr** is reserved for regional municipalities and **gp** is reserved for planning districts. See DMG (2007), Exhibit 4, pages 8-10 for definitions of these two ensembles.[4]
- All centroid numbers lie within the range 1-9,999 (i.e., 1-4 digits).

Thus, rather than pre-specifying a standard zone system, NCS22 specifies the criteria (listed above) that a valid NCS22 zone system must meet and standard node numbering ranges by spatial area (Table 3.1 below). This approach has the very strong advantage of permitting individual agencies to custom-tailor their zone systems to their individual needs. It does imply, however, the following requirements for modelling procedures in order to ensure their ability to handle user-customized zone systems:

- The software must be generic with respect to node numbering and ranges.
- Ideally, automated (or at least semi-automated) procedures exist for creating centroid connectors for custom zone systems so that networks can be converted from one zone system to another. Inro, for example provides tooling for this purpose, which is recommended for this application.

Also note that the lack of a universally adopted zone system may make exchange of data files challenging unless clear and unambiguous conversions from one zone system to another are available.

Three types of centroids are included in NCS22:

- "Regular" zone centroids. These, in turn, can be subdivided into zone centroids within the GTHA *per se* and centroids for "external" zones at the periphery of the GTHA that are included for modelling purposes. See Miller (2021) for a more detailed discussion of traffic zone system design and definition of zone centroid locations.
- "Station" centroids representing (typically higher-order) transit stations/stops.
- "Parking lots", for carpool parking, and other major parking facilities not associated with transit park & ride stations. These are not typically used in current models. But if they are to be implemented they are to be included in the station centroid range (new in NCS22).

In all cases, centroids are necessary any time one wants to model trips to/from a point in the network, since only centroids (as opposed to "regular" network nodes) can be sources of and sinks for (producers/attractors, origins/destinations) of trips in Emme. In particular, this is the reason that station centroids are often included in the network: so that access/egress trips to/from transit stations can be explicitly modelled. At a minimum, station centroids will be required at all transit stations that have park & ride / kiss & ride facilities in any model in which auto access/egress station choice is being explicitly modelled.[5] More generally, if access/egress station mode choice is to be modelled then all stations will require station centroids.

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[4] At the time of writing this report the Planning District system for the GGH is under review. If a new Planning District System is adopted, then this report will be updated accordingly.

[5] The primary alternative to this approach to modelling auto access to transit is to use auto auxiliary transit connectors from zone centroids directly to transit station nodes. This approach is rarely currently used in GTHA models and generally is not recommended.

For TMG base network development work, the zone numbering conventions adopted are detailed in Table 3.1. Points to note relative to NCS16:

- Station centroid numbering has changed. This will affect previous GTAModel networks.
- The numbering ranges for GTHA municipalities have all been incremented by 1000. This change has been implemented to align with the current GGHM coding convention.

Table 3.1 2022 TMG Base Network Zone Ranges

Region	Zone Centroids
Unassigned	1 - 999
City of Toronto	1000-1999
Durham Region	2000-2999
York Region	3000-3999
Peel Region	4000-4999
Halton Region	5000-5999
City of Hamilton	6000-6999
Niagara Region	7000-7199
Reserved for new regions	7200-7999
Haldimand-Norfolk Region	8000-8099
Brant County	8100-8199
Waterloo Region	8200-8499
Wellington County	8500-8699
Dufferin County	8700-8799
Simcoe County	8800-8999
Kawartha Lakes	9000-9099
Peterborough County	9100-9299
Northumberland County	9300-9399
External Zones or Gateways	9400-9499
Station Centroids	9500-9999

3.2 NODE NUMBERS

Similar to centroid numbering, the primary concern for non-centroid node numbering is that a clear, systematic numbering scheme is used that meets the following criteria:

- Exclusive right-of-way (EROW) transit lines (subway, GO Rail, LRT, BRT) are all coded with their own sets of nodes and links.
- High-occupancy vehicle (HOV) lanes similarly are all coded with their own sets of nodes and links.
- All other (i.e., non-EROW, non-HOV) nodes within a given regional municipality are grouped within a numbering range that is mutually exclusive from that used for other regional municipalities.
- Nodes that fall on the boundary between two municipalities need to be numbered in a consistent manner.

Unlike zone centroids, which inevitably will vary from one model system to another, network nodes should correspond to a standard numbering convention so as to facilitate the exchange and comparison of networks from one agency to another and to allow different model systems to readily operate on different networks. In particular, maintaining consistency between GGHM and GTAModel system node numbering conventions is a key criterion for defining the NCS22 node numbering ranges. These are shown in Table 3.2. Note that "External Zones/Gateways" refer to network nodes within zones external to the TTS (GGH) study area. If flow is to be generated to/from these zones/gateways then external zone centroids need to be coded (see Table 3.1).

Table 3.2 NCS22 Node Numbering Ranges

Region	Node Range
City of Toronto	10,000-19,999
Durham Region	20,000-29,999
York Region	30,000-39,999
Peel Region	40,000-49,999
Halton Region	50,000-59,999
City of Hamilton	60,000-69,999
Niagara Region	70,000-71,999
Reserved for new regions	72,000-79,999
Haldimand-Norfolk Region	80,000-80,999
Brant County	81,000-81,999
Waterloo Region	82,000-84,999
Wellington County	85,000-86,999
Dufferin County	87,000-87,999
Simcoe County	88,000-89,999
Kawartha Lakes Division	90,000-90,999
Peterborough County	91,000-91,999
External zones/gateways, Canada	94,000-94,999
External zones/gateways, US	95,000-95,999

EROW/HOV Type	Node Range
BRT/LRT nodes	96,000-96,999
Subway nodes	97,000-97,999
GO Rail nodes	98,000-98,999
HOV	900,000-999,999
Hypernetwork nodes	>100,000 & <900,000

3.3 NODE ATTRIBUTES

No node user fields (**ui1**, **ui2**, **ui3**) are specified in NCS22. The user is free to use these fields as required.

4 LINKS

In Emme, links are defined by their starting and ending nodes and so do not have an identifying number/label. Link attributes discussed in the following sections are:

- Mode.
- Length.
- Number of lanes.

- Function class / volume delay function (VDF).
- Speed.
- Lane capacity.
- Type (spatial classification).
- Extra attributes.

4.1 MODES

Modes are designated within Emme using a single-letter, case-sensitive code. Thus, a maximum of 52 modes might be defined. Each link must be coded with one or more mode codes, indicating what modes are permitted to use each link in the system. Emme supports four generic types of modes:

- *Auto* (personal vehicles).
- *Auxiliary auto* (other vehicle categories, including HOV and trucks).
- *Transit* (public/common carrier services).
- *Auxiliary transit* (transit access/egress walk; more generally non-auto/transit modes).

Table 4.1 defines the modes explicitly defined in NCS22, by mode type. Users may use unassigned codes to include additional modes as required by their specific modelling needs. The following sub-sections discuss these mode definitions by type in greater detail. The assignment of a given letter (lower- or upper-case) to a given mode is ultimately arbitrary in nature. By convention, however, lower-case letters have been used to represent "conventional" modes, and, where possible, the letter chosen is the first letter of the mode ("b" for bus; "m" for "metro", etc.). Upper-case letters are used to denote HOV, toll road or autonomous modes, and, where possible, correspond to the lower-case letter used for the conventional mode (e.g., d represents conventional light-duty trucks and D represents light duty trucks on toll roads).

4.1.1 Auxiliary Auto Modes

There are four types of auxiliary auto modes in NCS22: truck modes, HOV modes, bicycles and e-scooters. Allowance for specific representation of autonomous vehicles is also included.

Many roads have weight restrictions for vehicles heavier than 4.5 or 5 tonnes. Commercial vehicles that are lighter than these weight restrictions are classified as light trucks (Table 4.2). Medium or heavy trucks are vehicles that exceed the weight restriction. 4.5 tonnes have been used in this coding standard as the dividing line between light and other trucks, although it is noted that Highway 407 uses 5.0 tonnes in its definition.

High-occupancy lanes are only open to vehicles which have either 2+ or 3+ occupants (depending on the rules of local jurisdictions). For this reason, NCS22 includes mode designations for HOV2+ (2 or more persons in the vehicle) and HOV3+ (3 or more persons in the vehicle).

Table 4.1 Mode Code Definitions

Code	Type	Description
c	*Auto*	Personal vehicle, any occupancy
C	*Auxiliary Auto*	Zero-occupancy autonomous vehicle (ZOV)
d	*Auxiliary Auto*	Light truck
D	*Auxiliary Auto*	Light truck toll road
e	*Auxiliary Auto*	Medium truck
E	*Auxiliary Auto*	Medium truck toll road
f	*Auxiliary Auto*	Heavy truck
F	*Auxiliary Auto*	Heavy truck toll road
h	*Auxiliary Auto*	HOV2+ personal vehicle
H	*Auxiliary Auto*	HOV2+ toll road
i	*Auxiliary Auto*	HOV3+ personal vehicle
I	*Auxiliary Auto*	HOV3+ toll road
j	*Auxiliary Auto*	SOV personal vehicle
J	*Auxiliary Auto*	SOV toll road
k	*Auxiliary Auto*	Bicycle
K	*Auxiliary Auto*	E-bicycles
N	*Auxiliary Auto*	E-scooters
S	*Auxiliary Auto*	Light truck autonomous
T	*Auxiliary Auto*	Medium truck autonomous
U	*Auxiliary Auto*	Heavy truck autonomous
X	*Auxiliary Auto*	HOV2+ autonomous vehicle
Y	*Auxiliary Auto*	HOV3+ autonomous vehicle
Z	*Auxiliary Auto*	SOV autonomous vehicle
b	*Transit*	Local bus: 9m, 12m or articulated bus
B	*Transit*	Autonomous transit vehicles (shuttles, etc.)
g	*Transit*	Highway coach bus: GO Buses and intercity buses
l	*Transit*	LRT
L	*Transit*	Pearson LINK train
m	*Transit*	Subway
p	*Transit*	Premium bus service (not GO or intercity)
q	*Transit*	BRT (bus on exclusive right-of-way)
r	*Transit*	Commuter rail
R	*Transit*	UP Express
s	*Transit*	Streetcar
V	*Transit*	Via Rail
t	*Auxiliary Transit*	Transfer between two transit lines
v	*Auxiliary Transit*	Walk mode on centroid connector; in GGHM used for "incoming" connectors only.
w	*Auxiliary Transit*	Walk mode on a regular street link
y	*Auxiliary Transit*	Walk between park & ride lot and a transit station

Table 4.2 Suggested Definitions for Truck Modes

Mode	Type	Description
d	Light truck	Pickups and Trucks with a gross registered weight of less than 4,500 kg and used for commercial purpose.
e	Medium truck	Commercial vehicles with gross registered weight greater than 4,500 kg, and are single-unit vehicles of length not exceeding 12.5 metres.
f	Heavy Truck	Commercial vehicles with gross registered weight greater than 4,500 kg, and are multi-unit combination (tractor-trailer) vehicles of length exceeding 12.5 metres

Bicycles are included in the auxiliary auto (rather than transit) category since they are legally road vehicles, and, as more formal models of bicycle demand and performance possibly are developed within the region, they will likely be modelled in ways that are similar to cars and trucks. They are also subject to congestion in the same ways as cars and trucks rather than simply having a constant speed (as they would be under the auxiliary transit mode). Mode k represents conventional bicycles, while mode K represents e-bikes, in both cases either as a transit access/egress mode or as a regular mode of travel. Mode N has been included to permit future explicit modelling of e-scooters, if needed.

Typical practice in the GTHA has been to include motorcycle trips with auto trips, given the extremely small usage of motorcycles in the region. It is assumed that this practice will continue, although an explicit motorcycle mode could be added if this ever becomes necessary in the future.

4.1.2 Transit Modes

Transit mode codes are used to define primary transit technology-service categories. Additional detail concerning specific transit technologies (e.g., articulated bus versus regular bus) can be added through the vehicle definitions discussed Section 5.4. As indicated in Table 4.1, NCS22 includes mode designations for the following transit modes:

- Local bus: conventional (b); autonomous (B).
- Highway coach bus: GO Bus; intercity buses (g).
- LRT (l).
- Pearson LINK people-mover (L)
- Subway: heavy urban rail, not commuter rail (m).
- Premium urban bus service (such as Viva), not GO Bus or intercity bus (p).
- BRT: bus on exclusive right-of-way (q).
- Commuter rail: GO-Rail, including the Union-Pearson Express (r); Via Rail (V)
- Streetcar: not LRT; operations in shared rights-of-way (s).

4.1.2 Auxiliary Transit Modes

Auxiliary transit modes in Emme are typically used to model pedestrian movements to/from transit, but they can also be used to model general walk movements and other-mode movements that are not otherwise explicitly handled by the other modes in the network. It is very useful to differentiate different types of pedestrian movements that may either have different attributes or be used for different purposes in network modelling. The pedestrian movements explicitly represented in NCS22 are:

- t: transfer between two transit lines.
- v: walk on centroid connector.[6]
- w: walk on a regular street link.
- y: walk between a park & ride lot and a transit station.

"t" links should be included in the network whenever the transfer between two transit lines involves a significant walk (e.g., more than crossing a street or changing platform levels within a station). Typical examples where these transfer links should be used include the transfer between the Bloor-Danforth (Line 2) and University-Spadina (Line 1) subways at Spadina station and between the subway and GO Train stations at Union Station. They also are essential for between-agency transfers to support fare-based transit assignments, in which between-agency transfers may incur an additional fare being charged.

Two walk modes ("v" for centroid connectors and "w" for walk-on-road network) are included in the standard to facilitate fare-based network calculations (in which access fares may be coded into centroid connectors) as well as allow for the possibility of different speeds being used on the two types of links. "Walk-on-road" is included in the network so that transit users are not restricted to accessing transit nodes/lines that are directly connected to centroids via centroid connectors but can also "walk past" the closest transit service to access more distant, higher service lines. Note that for one one-way road links (e.g., Adelaide or Richmond Streets in downtown Toronto) walking needs to be coded in both directions.

4.2 LINK LENGTH

"Actual" link shape lengths are used for all links,[7] except for transfer links between HOV lanes and regular lanes, which have nominally small value such as 0.001m.The actual number of lanes available during the time period being modelled is used for all links, except for the cases shown in Table 4.3. Exclusive left turn and centre turning lanes are usually not explicitly coded, but lane capacities on such links can be adjusted to reflect the capacity increases represented by these extra lanes.[8] The typical default time period is the morning peak period. Note that if multiple time periods are being modelled with differing lane availabilities, these will need to be coded into separate network scenarios for each time period.

Table 4.3 Number of Lanes Definitions: Special Cases

Link Type	No. of Lanes
Centroid Connectors	2
Only Transit Modes	0

[6] The current version of GGHM uses two centroid connector walk modes: v is used for waking to the centroid and z is used for walking from the centroid. This is a rather non-standard conventional that we have chosen to not include in NCS22. Mode z is not assigned in NCS22, and so GGHM can continue to use these definitions if need be.

[7] Note that links coded in Emme are often not exact representations of actual roadway geometry and so the network distances computed in Emme may not precisely capture actual node-to-node distances.

[8] Since Emme does not explicitly model turning movements or split flows by lane, it is not appropriate to specifically code special turning lanes into the network.

4.3 Functional Class & Volume Delay Function Indices (*VDF*)

Volume delay functions (VDFs) are defined by a combination of link functional class and adjacent land uses (which can influence roadway performance). The **vdf** attribute, therefore, does double-duty as both the VDF index for link travel time calculations and as an indicator of link functional class. The NCS22 VDF definitions draw heavily on GGHM practice. Table 4.4 contains the VDF definitions and codes used in NCS22.

These definitions are derived from a combination of sources, including previous versions of the Network Coding Standard (NCS11 and NCS16), as well as the Geometric Design Guide and GGHM VDF definitions. As the geometric design guide does not give lane capacities, the capacities have been updated from NCS16, where necessary, to be consistent with GGHM standards. Specifically, lane capacities are defined on an assumed design capacity for Level of Service "D" as per the US TRB Highway Capacity Manual and speeds represent posted speed limits as the assumed link freeflow speed.

Posted speeds should be used in the network coding. "Freeflow speed" definitions that differ from the posted speed (e.g., using 110 kph for a freeway freeflow speed when the posted speed limit is 100 kph) is a modelling decision to be made at the discretion of the modeller.

Note that Emme VDFs must use link user fields as their arguments; they cannot use link extra attributes. As a result, key link attributes such as speed and capacity must be stored in user fields, as discussed in the following sections. Link user fields **ul2** and **ul3** are used for this purpose. Link user field **ul1** is not assigned a fixed purpose in NCS22, and so may be used at the user's discretion. The specification of the actual mathematical functional forms that define the VDFs is a modelling matter that is left to the user to determine. GTAModel, for example, uses "tangent functions", whereas GGH Model V4 uses BPR functions.

4.4 Link Speed (*UL2*)

Link user attribute **ul2** is reserved for link free-flow speeds (km/hr) for use in VDF calculations. The definition of link free-flow speed is a modelling issue, and different assumptions are used in various regional modelling systems. Posted speeds are recommended, which are stored in extra attribute **@lkspd** (see Section 4.9). The freeflow speed used in **ul2** can then be computed based on the posted speed as required for a given model system. For centroid connectors a uniform, non-congestion dependent speed of 40 km/hr is assumed.

4.5 Lane Capacity (*UL3*)

Link user attribute **ul3** is reserved for the lane capacities to be used in VDF calculations (autos/hr/lane). As in the case of link speeds, the definition of lane capacities typically involves modelling assumptions that may vary from one model system to another. Given this, NCS22 defines an extra attribute, **@lkcap** (see Section 4.8), that contains the calculated nominal link capacity, based on a defined set of rules. The assignment capacities used in **ul3** may then be computed by the user based in the user's model system assumptions. Table 4.4 provides recommended capacities by link type that are consistent with common practice.

Table 4.4 Link Functional Class & VDF Definitions

Area	Class	Subclass	Land use	Other Factors	Lane Capacity (pcu/lane /hr)	VDF
N/A	Freeways	Freeway			2000	11
		Expressway			2000	12
		Freeway Ramp			1400	13
		Toll highway			2000	14
		Toll highway ramps			1400	15
		Freeway/expressway HOV			2000	16
		Freeway/expressway HOV ramp			1400	17
		Freeway/expressway truck only				
Rural	Arterials	Long Distance Arterials		Unsignalized long distance arterials	1400	20
		Major Country Roads		Major roads with a greater number of signals	1000	21
	Collector	Collector Road	Main Street or Collector Roads		500	22
Suburban	Arterials	Principal urban arterials	Low density residential/ commercial development with no direct accesses	Long signal spacing and good signal coordination/ progression	1000	30
	Collector	Suburban Collector Roads			500	31
Urban	Arterials	Major urban arterials	Low/medium density residential or commercial with some accesses	Longer signal spacing, good level of signal coordination and green-time allocation	800	40
		Major urban arterial HOV	Low/medium density residential or commercial with some accesses	Longer signal spacing, good level of signal coordination and green-time allocation	800	41
		Minor urban arterials	Low/medium density residential or commercial with direct accesses	Closer signal spacing, occasional illegal parking causing interference	700	42
	Collector	Downtown/city centre roads	Roads in high density office/commercial (CBD) with high pedestrian activity, parking, etc.	Presence of street cars and cyclists	600	50
		Collector Roads	Roads providing access to local streets	All-way stops, traffic calming measures	500	51
N/A	Local	Centroid Connectors	Local Streets		9999	90

Note that if capacities change by the time period or day of the week being modelled (e.g., weekend versus weekday) then these will need to be coded into separate network scenarios for each time period or day being modelled (or stored in a user-defined extra attribute).

4.6 LINK TYPE (*TYPE*)

The 3-digit link type attribute is used to classify links by planning district (PD). Outside of the City of Toronto this corresponds to the link's area municipality. See the TTS 2016 Data Guide (Feb. 2018), pages 20-24 for PD codes.

If the code consists of two digits (the case for most PDs), then the first (left-most) digit should be coded as 0; if a one-digit code, then the first two digits should be coded as 0. Alternatively, the first digit may be used by modellers to store additional information concerning the link type/location. For example, in NCS16 the first digit indicates the link's jurisdiction for non-centroid connectors (Table 4.5). Or, the first digit might denote the regional municipality number.

For links that cross a municipal boundary the municipality within which the link's **i-node** is located defines the link's **type** value. Thus, for example, northbound links crossing Steeles Avenue between Mississauga and Brampton are coded as belonging to the City of Mississauga, while the southbound links are coded as belonging to the City of Brampton.

For links that define the boundary between two municipalities, the roadway centreline is assumed to mark the actual boundary. Thus the link **type** value is defined by which side of the centreline the link lies. Thus, for the same example above along Steeles Avenue, westbound links are coded as belonging to the City of Brampton, while eastbound links are coded as belonging to the City of Mississauga.

Table 4.5 NCS16 First Digit of Link Type Classification

First type digit	Classification
0	Centroid Connector
1	Federal
2	Provincial
3	Regional
4	Area Municipal
5	Private Sector
9	HOV ramp

4.7 SCREENLINE CODES

Links can correspond to one or more screenline. To identify them, the extra attributes @stn1 and @stn2 are used:

- **@stn1**: Screenline countpost flag attribute.
- **@stn2**: Screenline alternate flag attribute.

4.8 OTHER LINK ATTRIBUTES

Link user field **ul1** is not assigned within NCS22 and may be used by the user as needed.

Link extra attributes maintained within NCS22 network scenarios are:

- **@lkcap**: Link nominal capacity (veh/hr/lane).
- **@lkcst**: Personal vehicle link travel cost (excluding tolls) ($).
- **@lkspd**: Link posted speed (km/hr).
- **@toll**: Link toll charge, undifferentiated by vehicle class ($).
- **@toll1**: Toll for drive-alone autos ($).
- **@toll2**: Toll for 2-occupant autos ($).
- **@toll3**: Toll for 3-occupant autos ($).
- **@toll_mtruck**: Toll for medium trucks ($).
- **@toll_htruck**: Toll for heavy trucks ($).
- **@toll_zone**: Toll zone type code (additional codes may be added as needed:
    - 0: No tolls
    - 1: 407 ETR “light” zone.
    - 2: 407 ETR “standard” zone.

5 TRANSIT LINES

Each transit line (route) is defined by two components:

- A *header section* which defines attributes that apply to the entire line. Sections 5.1 through 5.4 describe these attributes, which are:
    - Transit line name.
    - Transit line description.
    - Transit line headway.
    - Transit line speed.
    - Transit vehicle mode and type.
- A *route itinerary section* that defines the path of the transit line through the network as a sequence of transit line *segments*. Each segment is defined by a *from*-node and a *to*-node. As described in Section 5.5, each segment has a set of attributes that include dwell time, layover time and a transit time function.

Two important points to note when coding transit lines are:

- For routes with multiple branches, each branch must be coded as a separate transit line with a unique identifier (see Table 5.1).
- While Emme allows looped lines, Inro still recommends that lines should be coded as two one-way routes. This allows for direction specific information. However, looped lines may be used as well, especially in cases of a pronounced "hammerhead" or “lollipop” shape. The extra transit line attribute **@loop** is used to determine what kind of line it is while the segment attribute **@loopcut** is used to show where the transit line was cut when converting from loop to one-way routes. For more information, see Section 5.4

5.1 TRANSIT LINE NAME & DESCRIPTION (*LINE* & *DESCR*)

Each transit line has a unique 7-character[9] alpha-numeric line name. Conventions for definition of each of the seven characters (numbering from left to right) are:

- Character 1: Region code. See Table 5.1 for definitions.
- Character 2: Sub-region code. See Table 5.1 for definitions.
- Characters 3,4,5: Route number. For one- or two-digit route numbers fill in characters to the left of the route number with zeros.
- Character 6: Branch letter ("A", "B", etc.).
- Character 7: Line direction. Most transit routes are coded as two lines, one travelling in each direction. These should be labelled "a" and "b", at the coder's discretion, to differentiate between the two directions. For "looped" lines, it is recommended that lines running "clockwise" be labelled "a" and lines running counter-clockwise be labelled "b".

Note that, in addition to its name, each line has a text description of up to 20 characters to further identify the line. Also note that blank line definitions are not permitted in Emme.

5.2 LINE HEADWAY (*HDWY*)

The line headway is generally defined as the average time between transit vehicle arrivals for the service period being modelled. Note that if multiple time periods are being modelled and if headways vary across time periods, then different network scenarios will be required (with appropriate headways coded into each scenario) for each time period (or, these headways could be stored in user-defined extra attributes).

No standard GTHA-wide definition of the morning peak period (or other service periods within the day) currently exists, with both 6:00-8:59 and 6:30-9:29 being used in various model systems. From a network coding standard point of view a standard set of operating period definitions is not essential. The exchange of data, models and network information among agencies, however, would certainly be facilitated if standard definitions were used.

For GO Transit (or any other transit service operating relatively infrequently), care must be taken to properly describe the service's "headway" for network assignment purposes so that the effect of the headway on transit line assignments is neither grossly over- or under-estimated
How headways are handled represent modelling assumptions rather than "base data". In keeping with the NCS22 philosophy of not embedding modelling assumptions into base networks, but rather only incorporating actual service attributes, in NCS22 an extra transit line attribute (**@trrun**, see Section 5.5) is used to store the number of runs in the period for each transit line, leaving it to the user to compute the "headway" as a modelling assumption (i.e., similar to the recommended approach to link speeds and capacities).

[9] Note that this is change from previous coding standards, which used 6 digits. Adding an extra digit avoids a potential conflict in the usage of the second digit in previous standards. Specifically, it allows for a two-digit region-subregion code and a three-digit route number.

Table 5.1 Transit Line Region Codes

1st Char.	Region	Transit Agency	2nd Char.	Remaining Characters
B	Brampton		N/A	Middle Characters: Digits of route number (right justified, padded with zeroes)
B	Brant	Brantford	B	
D	Durham	Regional	N/A	
D	Dufferin	Orangeville	O	
G	-	GO Bus	B	
		Go Rail	T	
H	Halton	Oakville	O	
		Milton	M	Last character: Route branch code (usually A-Z)
		Burlington	B	
K	Kitchener/Waterloo	Grand River Transit	N/A	
LINK	Link at Pearson Airport	Link Train	N/A	
M	Mississauga	Mississauga	N/A	e.g. M057b,
N	Niagara	Cobourg Transit	C	
		Fort Erie	F	
		Lincoln	I	
		Niagara Falls	N	
		Niagara Region	R	
		Niagara-on-the-Lake	L	
		Pelham	E	
		Port Colborne	P	
		Port Hope Transit	H	
		St. Catherines	S	
		Welland	W	
P	Peterborough	Peterborough	P	G9001E,
S	Simcoe	Barrie	B	
		Collingwood	C	
		Midland – Penetanguishene	M	
		Orillia	O	
		Simcoe-Linx	L	
		Wasaga Beach	W	
T	Toronto	TTC (Bus and Streetcar)	N/A	
		TTC Train	S	T501a
W	Hamilton	HSR	N/A	
W	Guelph		G	
Y	York	Regular route	N/A	
		Bradford West Gwillimbury	B	
		Viva route	V	
		Other non-municipal transit	-	Last char: Special code

5.3 LINE SPEED (*SPD, TTF* & *US1*)

Transit line speeds may be defined in two ways. The first is to define a default operating speed for the entire line in the **spd** line attribute. These average line speeds are computed based on schedule data. The second method is to define speeds on a segment-by-segment basis using a transit time function (TTF) (**ttf**, see Section 5.5); TTFs may vary from one segment to another on the same line if need be. The line default speed is used for all segments that do not have a transit time function defined. The user segment field **us1** is used to define segment-specific speeds that are used in the segment TTFs.

Firm rules concerning when to use TTFs (or TTF definitions) are not included in this coding standard. To avoid inadvertent usage of incorrect data, however, the following conventions are explicitly introduced in NCS22:

- When segment-based speeds are used for a line, **spd** = 0 for this line.
- When average line speeds are used, **us1** = 0 for that line's segments.
- Average transit line speeds include dwell times.
- Dwell times are defined as the time from when a transit vehicle door opens to the time it closes. Unless more detailed data are available, dwell times should be set to a nominal value of 0.01 min (0.6 secs).[10] Segments without boardings and alightings (e.g., non-stop segments) should use a dwell time of 0.0.
- One-way average transit line speeds should <u>exclude</u> end-of-line terminal and recovery times.
- Segment speeds should include the average time lost due to acceleration and deceleration; i.e., the speed should be the average stop to stop travel time.

5.4 TRANSIT VEHICLE & MODE

Each transit line must have a unique mode and transit vehicle type. Each vehicle type must have the following attributes:

- Vehicle type number.
- A 10-character code.
- Seated capacity (passengers).
- Total capacity (passengers).
- Auto equivalency factor (passenger car equivalents / vehicle).

NCS22 vehicle capacities are based on typical loading standards set by local transit agencies and Metrolinx for service planning, rounded to the nearest 10 passengers for high-capacity modes and rounded to the nearest 5 for lower-capacity modes. Capacities for rapid-transit modes have been calculated from the following formula:

Total capacity = seats + (allowed density) * (floor area of the vehicle)

where the allowed density for exclusive-ROW vehicles being 3.0 pass / m^2; and the density for mixed-ROW vehicles being 2.34 pass / m^2. Note that GO buses do not permit standees due to

[10] Note that Emme does not allow stop dwells of zero, so a small nominal non-zero value is always required.

safety restrictions and that GO rail services currently target a 100% seated load with zero standees.

Table 5.2 lists the vehicle definitions supported in NCS22. Some vehicle IDs have been 'reserved' for vehicles expected to enter into service in the next decade. Furthermore, note that more than one vehicle type may be associated with a given transit mode. Additional vehicle types can always be added to a model system as required.

Table 5.2 NCS22 Transit Vehicle Definitions and Attributes

ID	Description	Code description	Mode	Seated Capacity	Total Capacity	Auto Equiv.
1	GO Train (12-car)	GoTrain12	r	1900	2400	-
2	GO Train (10-car)	GoTrain10	r	1600	1760	
3	GO Train (6-car)	GoTrain6	r	900	1200	
4	Subway (6-car, Rocket)	Sub6carRkt	m	400	1100	-
5	Subway (6-car, T1)	Sub6carT1	m	400	1000	-
6	ICTS train (SRT)	SRT4car	m	260	740	-
7	Subway (4-car, T1)	Sub4carT1	m	260	670	-
8	Line Train (proposed)	SubOL	m	120	600	
9	SRT Train	SRTtrain	m	120	220	
10	MLX LRV 3		l	168	492	12
11	Light rail vehicle (3-car)	LRV3car	l	210	390	
12	Light rail vehicle	LRV	l	120	336	
13	MLX LRV 2		l	112	328	8
14	UP Express	UPX3car	r	173	307	-
15	Light rail vehicle (2-car)	LRV2car	l	140	260	
16	LINK Train		L	56	175	-
17	ION LRV	LRVion	l	56	160	-
18	Streetcar LFLRV (30m)	LFLRV30	s	70	130	4
19	Streetcar ALRV (23m)	ALRV23	s	60	110	3.5
20	Articulated bus (60ft / 18m)	Bus18	b	55	85	3
21	Double-decker coach bus	DblDeckBus	g	80	80	2.5
22	Streetcar CLRV (16m)	CLRV16	s	45	75	3
23	Deluxe bus (60ft / 18m)	Deluxe18	b	55	85	3
24	Coach bus	GoBus	g	55	55	2.5
25	Premium Bus	BusPrem	b	35	55	2.5
26	Bus (40ft / 12m)	Bus12	b	35	55	2.5
27	Deluxe bus (40ft / 12m)	Deluxe12	b	35	45	2.5
28	Bus (30ft / 9m)	Bus9	b	25	40	2.5
29	BRT bus (currently unused)	BRT	q	*Reserved for future expansion*		
30	Light rail vehicle (currently unused)	LRV	l			

5.5 TRANSIT LINE & SEGMENT ATTRIBUTES

Transit line user field definitions are:

- **ut1** is used to store a transit line operator code, see Table 5.3. This code is useful for various operator-specific network calculations.
- **ut2** is the transit in-vehicle travel time perception factor.
- **ut3** stores line-specific boarding penalties. This can be used to distinguish lines with quicker access (e.g., due to all-door boarding and off-board fare payment, such as Viva and Zum), or to penalize lines/services for which transfers carry a higher weight.

Extra attributes for transit lines and segments are:

- **@trrun**: Used to store the number of runs in the analysis time period for each transit line, leaving it to the user to compute the "headway" (attribute **hdw**) as a modelling assumption. This attribute only needs to be defined (i.e., non-zero) for low-frequency routes for which normal (actual) headway-based calculations are inappropriate (e.g., many GO Transit routes, other low-frequency express or special service routes, etc.). For these routes, **hdw** should be set equal to zero in the base network. Users can then define the **hdw** attribute for these routes as part of their modelling assumptions.
- **@loop**: A transit line extra attribute used to indicate treatment of loops within this line. **@loop** codes:
  - 0, the line is not looped.
  - 1, the line is looped and has been coded as looped.
  - 2, the line is looped but has been split into two one-way routes within the coded network.
- **@loopcut**: A transit segment attribute that is used to show the location of the split if the line has been split from a looped line into two one-way lines (i.e., **@loop** = 2). The value of **@loopcut** is the J node of the segment at which point the line was split and 0 for all other segments.

- Each transit line itinerary is made up line segments, with each segment between defined by two nodes in the itinerary list. Each segment may be described by some or all of the attributes listed in Table 5.4. Segment-specific attributes apply only to the segment immediately following the attribute specification in the itinerary definition, while other attributes continue to apply to all subsequent segments until they are redefined within the itinerary definition. See the Emme user's manual for further details.

Table 5.3 Transit Line Operator Code (ut1)

Transit Line Code	Transit Agency
B	Brampton
BB	Brantford
D	Durham Regional
DO	Orangeville
GB	GO Bus
GT	Go Rail
HB	Burlington
HM	Milton
HO	Oakville
K	Grand River Transit
LINK	Link Train at Pearson Intl' Airport
M	Mississauga
NC	Cobourg Transit
NE	Pelham
NF	Fort Erie
NH	Port Hope Transit
NI	Lincoln
NL	Niagara-on-the-Lake
NN	Niagara Falls
NP	Port Colborne
NR	Niagara Region
NS	St. Catherines
NW	Welland
PP	Peterborough
SB	Barrie
SC	Collingwood
SL	Simcoe-Linx
SM	Midland – Penetanguishene
SO	Orillia
SW	Wasaga Beach
T	TTC (Bus and Streetcar)
TS	TTC Train
W	HSR`
WG	Guelph
Y	York Region Transit
YB	Bradford West Gwillimbury
YV	Viva route

Table 5.4 Transit Line Segment Attribute Summary

Keyword	**Description**	**Default**
dwt	Dwell time per line segment (minutes)	0.01
dwf	Dwell time factor per length unit (minutes/km)	Not used
path (yes or no)	Nodes on line can or cannot be omitted	Yes
ttf	Transit time function on links and turns	0 (use line speed)
ttfl	Transit time function on links only	0
ttft	Transit time function on turns only	0
us1	Exclusive right-of-way speed (kph)	0
us2, us3	Segment user data fields	Available for model-specific use
lay	Layover time (segment specific, can be used for one intermediate segment) (minutes)	0
tdwt	Temporary dwell time (segment specific) (minutes)	0
tus1, tus2, tus3	Temporary segment user data storage	Available for model-specific use

6 References

DMG (2007) *Transportation Tomorrow Survey 2006 Version 0.1 Data Guide*, Toronto: Joint Program in Transportation, December.

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TMG (2015) *Fare Based Transit Networks: Hyper-Network Generation Procedure and Specification.* Toronto: Joint Program in Transportation, June 10.