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Publication of this paper sponsored by Committee on Public Transportation Planning and Development.

Integrated Transit-Network Model (INET): A New Urban Transportation Planning System Program

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The Integrated Transit-Network Model (INET) is a new Urban Transportation Planning System (UTPS) computer program for analysis of transit systems. Its objectives are to account for the interaction of highway and transit networks, exploit existing highway network data, provide for accurate but simple and inexpensive transit-network coding, provide input for other UTPS programs, furnish useful evaluative reports, and help bridge the gap between systems and operations planning. A small transit network is hypothesized to demonstrate INET's features and explain its assumptions, mechanics, and operation. Special subjects are route layout, cruise and stop delay time, exclusive and mixed rights-of-way, scheduling, and cost and impact estimates. There is a brief discussion of INET's use with real transit and highway data; the results testify to INET's exceptional simplicity and accuracy.

The Urban Transportation Planning System (UTPS) is a set of computerized and manual tools that aid analysis of urban transportation problems; the system was developed and distributed jointly by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA).

The Integrated Transit-Network Model (INET) is a new UTPS program by means of which planners can study the interaction of transit (bus) service and automobile service on shared rights-of-way. By using available highway network information, INET greatly simplifies coding. It cuts data collection costs and allows the study of more alternatives with no increase in cost.

INET needs only the simplest and most-straightforward network description but produces detailed estimates of service, resources, and impacts. INET writes a file of the transit network for analysis by other UTPS programs that analyze the shortest path, impedance, cost, passenger loading, and other factors.

GOALS AND CAPACITIES

INET's goals are to reveal the interaction of highway and transit systems, exploit existing highway network data, facilitate accurate but inexpensive coding, provide input to UTPS, give planners useful reports, and help bridge the gap between systems and operations planning.

INET unites descriptions of highway and transit systems. Since the transit-system coding references the already-coded highway network, separate maps and data bases are not needed: The transit system simply overlies the highway system.

Therefore, INET coding of existing and planned systems is much faster than the old UTPS separate-network process (1); its simplicity will become apparent in the examples below. The clarity of the new process means that planners can learn it quickly and become versatile with it.

INET's great conceptual benefit is consistency in the highway-transit network, since most public transit consists of buses on street systems in mixed automobile traffic. In such traffic, bus speed is a function of (among other things) automobile speed. Since automobile speed is part of the highway-system description, INET represents both modes and both systems. Since INET's automated treatment of highway-transit interaction supports models of multimodal supply-and-demand equilibrium (2), INET can automatically investigate the impact on transit of changes in the highway system and demand.

INET allows indirect study of those few links on which bus traffic slows automobile traffic. (Now a printed report, this function will soon be automated.)

Since all transit service cannot be represented on the highway network, INET will code exclusive rights-of-way (such as those for rapid rail) separately.

INET brings together traditional systems planning and short-range operations planning. For long-range use, INET analyzes alternatives quickly by using appropriate macroscopic coding. For short-range use, especially promising alternatives (or portions of them) can be studied and more detail can be added. INET computes the time of day or night that a trip on a line will arrive at a particular point, so planners can study multitudes of options and still produce a rough service schedule.

INET accepts existing or proposed schedules, so current service can serve as an analytical base-line. INET can use an existing system description (which includes schedules) to evaluate short-range service modifications.

UTOWN: INET CODING SCHEME

In the hypothetical Utown, the central business district (CBD) abuts on a lake and is separated from the rest of the region by a river. The arterial street system is simple, and a north-south freeway runs west of the CBD.

Coding Utown's Highway Network

A UTPS highway network is coded for Utown (Figure 1). The five transportation-analysis zones are numbered 1 through 5. The network is highly aggregated, so only arterials and the freeway are coded explicitly. Each coded link stored in the network file contains information such as the A node and the B node, the distance, the number of directional lanes, the automobile travel time, and the type of link facility and link area. Automobile speeds are estimated on each link by equilibrated (capacity-restrained) traffic assignment of peak automobile trips to the Utown highway network. These speeds can be directly estimated by the planner and input on highway-link data cards.

Example 1: Preliminary Route Layout

Utown citizens want a new bus route, the Green Hornet, between the western suburbs and the CBD (Figure 2). Note in Figure 2 that the inbound route starts at highway node 127, mixes with automobile traffic through nodes 108, 126, and so on, and terminates at node 102. The outbound route is the reverse. Also, note that there are bus stops at nodes 127, 124, 103, and 102 to serve zones 4, 2, and 1. The proposed headway is 20 min.

The preceding information (the minimum data needed to describe a line) is input to INET with appropriate key words on an &ROUTE card; at least one &ROUTE card is used for each line. (The use of more than one &ROUTE card is introduced in the section entitled "Further Examples.")

The coded &ROUTE card for the proposed bus line would be set up as follows:

```
&ROUTE M = 4, L = 10, H = 20, N = -127, 108, 126,
   -124, 123, -103, 122, 119, -102, &END.
```

There may be as many as 1200 &ROUTE cards to describe the lines in a network. A card may be more than one card image in length, like all UTPS control cards. &ROUTE cards follow the general UTPS coding conventions (3).

A line is identified on the &ROUTE card by a mode number (M) and a line number (L). M ranges from 4 to 8, and L can range from 1 to 255. In the example above, the mode is specified as 4 (M = 4), the line number as 10 (L = 10), and the headway as 20 min (H = 20).

The line's route appears as a sequence of node numbers (N) present in the highway network. Adjacent nodes imply a link. From the sample &ROUTE card shown above, . . ., 126, 124, 123,. . . implies two links: 126 to 124 and 124 to 123. Those nodes where passenger activity occurs (e.g., bus stops and stations) carry a minus sign. In this line description, a bus stops only at nodes 127, 124, 103, and 102. The other nodes only specify the route.

If the running-time calculation (described later) is adequate for planning, only four key words (M,L,H,N) need be coded to describe a line. Other key words and data could complement these four key words (as described elsewhere).

INET OUTPUTS, CALCULATIONS, AND CODING DETAILS

With only the information from an &ROUTE card such as that just described, INET produces a detailed route description (Figure 3). A look at this description reveals several of INET's functions.

The "Headway" section has the values Nominal, Maximum, Factor, and Actual. If an Actual headway (H) is not coded, INET calculates the best headway between a given nominal headway (NH) and a maximum headway (MH). The headway value Factor (FH) is optional. H is the actual fixed time in minutes between servicings by vehicle crews. If H is coded, the other three parameters are not, and INET cannot adjust the headway. Not coding H and coding NH and MH instead lets INET adjust the headway for more-efficient or more-productive service.

NH is a rough estimate of the minutes between servicings by vehicle crews and lets INET calculate a revised headway.

MH is the upper bound to which INET can adjust NH to conserve a vehicle crew. The UTPS transit-assignment program ULOAD uses MH to revise a headway for ridership at a peak load point. ULOAD never calculates a headway greater than the specified maximum. Hence MH can be called a policy or courtesy headway.

FH is a time specified to ensure headways that correspond to clock times or to synchronize line schedules with a common transfer point. When FH is present, NH and MH must be multiples of it; headways revised by INET will be multiples of FH. For example, if FH = 10, the calculated headway is constrained to multiples of 10 min.

The value listed after "Vehicle-Crews" is the number of crew units needed, computed from headway, layover time, and running time. The heading "Capacity" for the line (in passengers per hour) is the actual headway divided into a user-specified vehicle capacity ("Pass/Veh," see Figure 3).

Under the heading "Company," there is a user-specified integer between 1 and 99 used by INET in summary reports. It lets the user group lines

Figure 1. Utown highway network.

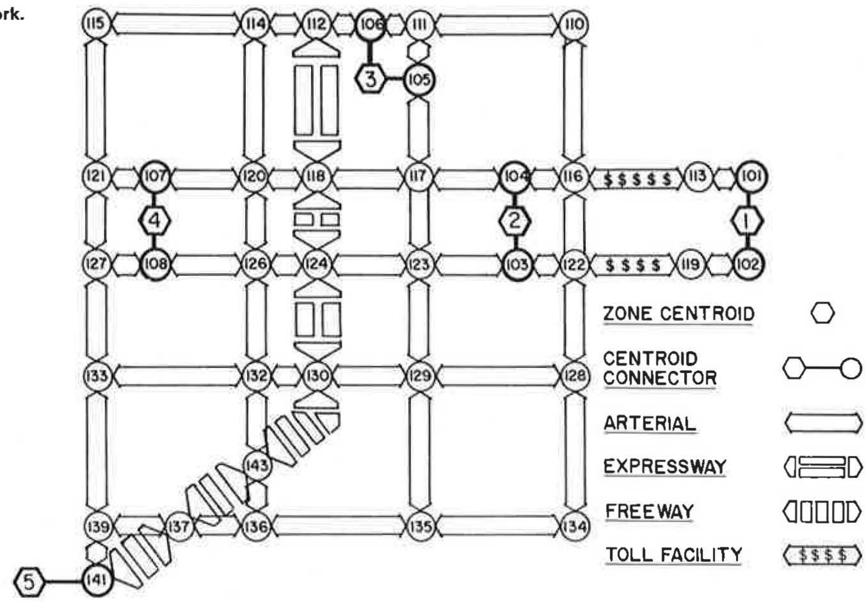


Figure 2. Green Hornet transit line.

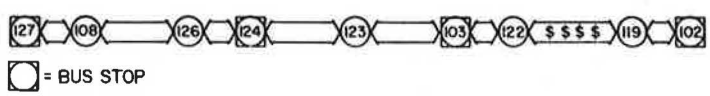


Figure 3. INET Report 8: detailed route description.

```
M O D E   4     L I N E   10

----------HEADWAY---------- VEHICLE-CREWS:      8           COMPANY:  1
NOMINAL:   0.0  FACTOR:  1.0 CAPACITY (PPH):   150        TECHNOLOGY:  1
MAXIMUM:  60.0  ACTUAL: 20.0 PASS/VEH:  50,  MIN LAYOVER:  3.0 MINS,  0%

---------READ DOWN (TRIP  1)---------  --------READ UP (TRIP  1)-------
------ROUTE------- -------LINK-------  ----ROUTE---- -------LINK-------
NODE TIME   DIST SP TIME  DIST SP DS W  TIME  DIST SP TIME  DIST SP DS W
---- ----   ---- -- ----  ---- -- -- -  ----  ---- -- ----  ---- -- -- -
 127 0800                               0853 10.60 12  4.9  1.40 17  0 0
 108         1.40 17  4.9  1.40 17  0 0        9.20 11  4.6  1.60 21  0 0
 126         3.00 18  5.2  1.60 18  0 0        7.60 10  6.5  1.00  9  0 0
 124 0817    4.00 14  6.6  1.00  9  0 0  0837  6.60 11  9.0  2.00 13  0 0
 123         6.00  9 22.5  2.00  5  0 0        4.60 10  8.7  1.20  8  0 0
 103 0850    7.20  9 11.0  1.20  7  0 0  0820  3.40 10 10.4  1.80 10  0 0
 122         9.00  8 13.6  1.80  8  0 0        1.60 10  1.0  0.0   0  0 0
 119         9.00  8  1.0  0.0   0  0 0        1.60 12  8.2  1.60 12  0 0
 102 0926   10.60  7 21.2  1.60  5  0 0  0800

FIRST TRIP:                      0800.0                          0800.0
LAST TRIP:                       0900.0                          0900.0
TRIPS:                                4                               4
ROUTE MILES:                       10.6                            10.6
RUN TIME (MINS):                   86.0                            53.1
LAYOVER (MINS):                    14.0                             6.9
TRIP TIME (MINS):                 100.0                            60.0
% LAYOVER:                           13                              11
'COST' INDEX:                      3143                            1891

AREA TYPE        1    2    3    4    5        1    2    3    4    5
CODED ST/MI    0.6  0.3  0.3  0.0  0.7      0.6  0.3  0.3  0.0  0.7
SDT FACTOR     8.0 12.0 12.0  1.0  4.2      8.0 12.0 12.0  1.0  4.2
```

with site-specific, administrative, or other significance (e.g., garage, service corridors, and traditional transit lines).

Under "Technology," there is an integer between 1 and 8 that allows the user to associate a set of impact rates (energy or fuel consumption and pollutant emission) with each mode. These rates are applied for the appropriate mode to vehicle-crew miles to estimate aggregate system values for energy consumption and pollutant emission. (These values operate in another INET report that is discussed under the heading "Further Examples.")

The minimum layover ("Min Layover") is the greater of two user-specified parameters: a number of minutes or a percentage of running time. Values may be specified by line on an &ROUTE card or defaulted on an &PARAM card that provides mode-specific default values.

The line is reported for both directions. In Figure 3, "Read Down" displays the links from left to right on the &ROUTE card. "Read Up" displays them from right to left. Under these headings, there are two subheadings, "Link" and "Route."

Transit-Link Speed

The most-important link information in Figure 3 is probably the transit-link speed (SP), a value calculated from highway speeds, transit-vehicle performance, and delay from passenger service stops. In determining a line's speed, INET uses various parameters; these include the type of right-of-way, known as the way type (W). W is coded on the &ROUTE card as one of four values:

1. W = 0, transit in mixed automobile traffic (default);
2. W = 1, transit on reserved lane or lanes;
3. W = 2, transit on contraflow lane or lanes; or
4. W = 3, transit on exclusive guideway.

Since INET's default value is W = 0, there is rarely need to code W. INET infers the cruising speed of a transit vehicle from the average automobile speed on the shared link. INET's simple transit-speed model assumes that a link time is the sum of the vehicle's cruising time along the link plus a stop delay time. Cruising time is the time the vehicle takes to traverse the link with no stop at either node. Stop delay time accounts for slowing down, stopping, and starting up at the A node or the B node.

Cruising Time

The calculation of transit cruising time is automatic and straightforward; it varies with W and with area type. For transit in mixed traffic (W = 0), the cruising-speed calculation uses a highway-transit speed conversion function and the highway speed on the network description (HR). HR derives from a UROAD (equilibrium) traffic assignment or is manually specified for the highway link as an estimated speed. The calculation uses a simple piecewise linear relationship to translate highway-link speed to transit-link speed. INET has one such function for each mode (M = 1-8) and highway-link area type (1-5). INET's user may change any of the 40 functions (eight modes multiplied by five area types) to reflect site-specific performance by using speed-function update cards.

To calculate a link's transit cruising time, INET first enters the highway-transit speed function with the link's highway speed (from the network file) to obtain the transit cruising speed. For mixed traffic (W = 0), INET uses the congested or estimated highway speed. For transit running on a reserved (W = 1) or contraflow (W = 2) lane, the speed is that of free-flowing automobiles. Given the cruising speed, INET obtains the cruising time by dividing the speed into the link distance from the network file ("Dist" column in Figure 3).

For transit running on an exclusive guideway (W = 3), INET calculates cruising speeds in the same way as for a reserved or a contraflow lane. However, if the link is not in the highway network, INET calculates the distance for an exclusive guideway link from the XY-coordinates of the nodes present in the network data base. If the link is in the network, INET uses coded highway distance. Since an exclusive guideway is rare, it is normal to specify line speed on the &ROUTE card, as described in Example 3 in the section "Further Examples." INET can also input special transit links with speed or distance information, as described in Example 4 in the same section.

Stop Delay Time

Stop delay time (SDT) is added to a link whenever the link has a stop at the A node or the B node. SDT is the sum of dwell time and acceleration and deceleration time. INET finds the dwell time (in minutes) in a table it has indexed by the line's mode (M) and the link's area type. The acceleration (deceleration) time is calculated from the vehicle acceleration rate (in miles per hour per second) from the same table and the cruising-speed profile. The dwell time and acceleration table provide default values, which may be overridden.

It is important that SDT calculations reflect aggregation in network coding. If one coded stop in the network represents five actual bus stops, the computed SDT must be five times the average per-stop delay. SDT can be modified by a stop density factor, also tabulated by mode and area type. Supplied by the INET user, the stop density, in actual stops per mile, is used to represent the true number of stops automatically.

If INET's method of link-time calculation is inappropriate, overriding values can be used in line descriptions. The two key words are speed (S) and SDT. Any &ROUTE card's S or SDT may be values the user wishes INET to associate with all line (or line-segment) links. (See Example 4 in "Further Examples.")

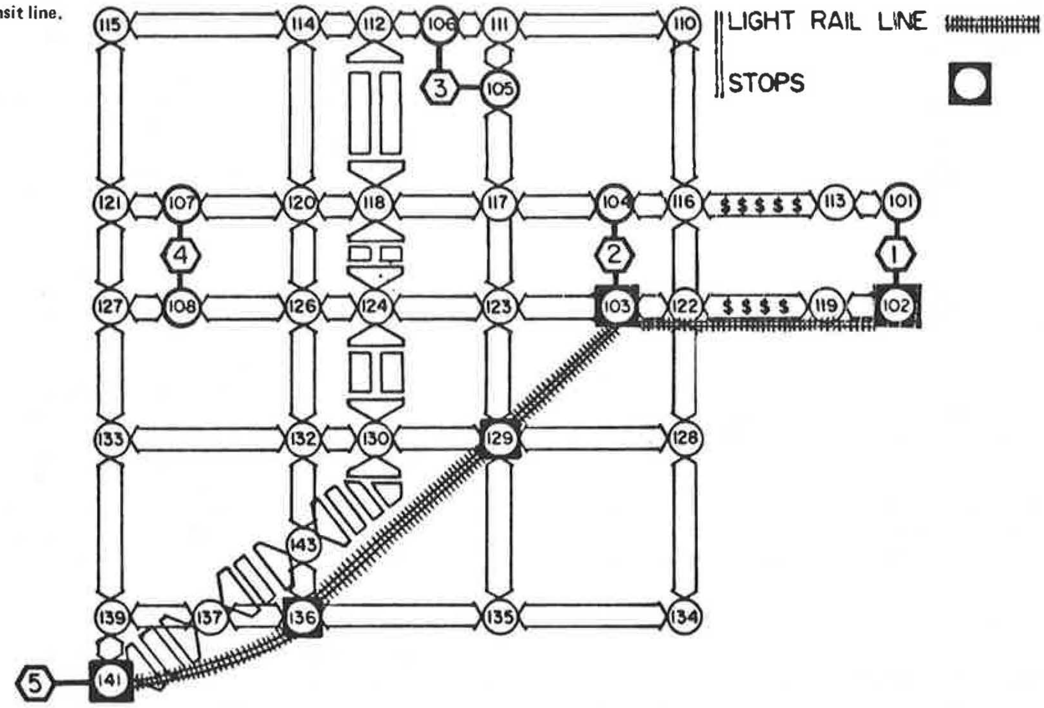
Under the heading "Route" in Figure 3 there are four columns: "Node," "Time", "Dist," and "SP." "Node" describes the line's route through the highway network as given with the node-sequence key word (N) on the &ROUTE card. "Time" shows the estimated clock times at which one trip will reach each stop (discussed below). "Dist" is the cumulative distance in miles. SP values are the cumulative average speed of the vehicle on the line along the route, which is based on bus running speed and SDT.

Nontransit Links

The final element needed to describe the line is supporting nontransit links (e.g., walk links or automobile connector links) that connect transit service with zone centroids (1). For the line in Figure 2, there are walk connector links from 4 to 108, from 2 to 103, and from 1 to 102 (where 4, 2, and 1 are the zone centroids shown in Figure 1). INET specifies nontransit links in the same way that it does transit lines: The &ROUTE card references the highway network, and links are described in the node sequence (N).

For Example 1, the nontransit links would be

Figure 4. Light Flash transit line.



described as follows [the key words for nontransit links are mode (M), link group (LG), node (N), and way type (W)]:

```
&ROUTE M = 1, LG = 1, N = 2, 103, -1, 102 &END.
&ROUTE M = 1, LG = 2, N = 4, 127, W = 3 &END.
```

N gives a node sequence in which adjacent numbers mark links, but links with a negative B node are not included. In the example above, node 127 is not connected to node 2, and 103 is not connected to 1. Thus, three separate mode-1 links are described: 4 to 127, 2 to 103, and 1 to 102.

INET calculates non-transit-link times in the same way that it does transit-link times. Cruising time is a function of a speed dependent on mode and area type. (There is, of course, no SDT.)

FURTHER EXAMPLES

Example 2: Expanded Line Information

Suppose that the proposed line in Example 1 is analyzed further by means of UTPS software and that demand estimates show it to be feasible. A more-detailed service study is now required: time of operation, vehicle crews, and a first attempt at scheduling.

The line (Figure 2) will run from 8:00 a.m. to 9:00 a.m. daily. The scheduling department reports that the minimum layover time at the end of a run is 10 min or 10 percent of trip time, whichever is longer. With only these data, INET can estimate additional vehicle crews needed and make a first attempt at scheduling.

This information adds three key words to the &ROUTE cards for the line--"Period," "Lay," and "LPC" (explained below):

```
&ROUTE M = 4, L = 10, H = 20.0; Period = (0800,
   0900);
LAY = 10.0; LPC = 10; N = -127, 108, 126, -124,
  123, -103, 122, 119, -102 &END.
```

"Period" specifies a service period with two numbers--the time that the first run begins (8:00 a.m.) and the time that the last run begins (9:00 a.m.). This period is used (with trip calculations) to print out the first run's arrivals at each stop (i.e., a partial line schedule or headway sheet).

Minimum layover (Lay) is used to calculate the vehicle crews needed to serve the line at a given headway. Here, Lay = 10.0. The percentage of running time (LPC) sets the minimum layover at 10 min or 10 percent of the running time, whichever is greater.

INET Report 8 (Figure 3) displays the detailed description of the line M = 4, L = 10. Note that the clock time of the first run's arrival at each stop appears in the "Route-Time" column. The time at node 127 is 8:00 a.m., the time at node 124 (the next stop) is 8:17 a.m., and so on. These times are computed from bus running time and SDT, as described earlier.

Computation of a total, rough operating cost index for the time period is based on up to three factors: vehicle-crew miles, hours, and units.

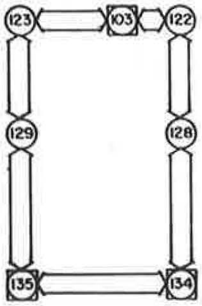
The report shows that eight vehicle crews are needed at a headway of 20 min, calculated from headway, line running time, and minimum layover time.

INET defines two-way bus lines as (a) moving symmetrically in both directions in the node sequence N shown on the &ROUTE card, (b) having the same headway in both directions, and (c) being served by the same vehicles in both directions. INET synchronizes outbound departure times and the inbound linking trip. The result will be less than or equal to the number obtained by treating each direction separately, estimating vehicles for each, and adding the two.

Example 3: Varying Way

More than one &ROUTE card is used to describe a transit line with varying way type (W). As in Figure 2, the line will use normal streets and a contraflow lane, and a high-occupancy-vehicle (HOV) lane is proposed for the Utown freeway. The HOV

Figure 5. Blue Loop transit line.



lane would serve only buses and carpools at peak periods with limited stops. The line can be coded as follows:

```
&ROUTE M  = 4, L = 40, H = 30; Period = (0700, 1000);
  N = -106, 112 &END.
&ROUTE M = 4, L = 40, N = 112, 118, -124, W = 2
  &END.
&ROUTE M = 4, L = 40, N = -124, 123, -103, 122, 119,
  -102, W = 3 &END.
```

Note that three &ROUTE cards are needed due to the change of way type from local streets (W = 0, default), to contraflow (W = 2), and to HOV lane (W = 3). Nominal line characteristics (such as headway, layover time, and time period) need be specified only on the first &ROUTE card for that line.

Example 4: Exclusive Guideway

As shown in Figure 4, a light rail transit (LRT) line is proposed from the southwestern suburbs along an abandoned rail right-of-way to the CBD. Some of the rail right-of-way follows highway links, but some of the proposed LRT guideway follows no existing street segment. INET readily accommodates the latter condition, either with link data cards or directly with &ROUTE cards. The &ROUTE cards are by far the simplest way to code exclusive guideways due to availability of highway nodes.

Link Specification by Using &ROUTE Card

Transit links not in the highway network may also be input on &ROUTE cards, given three constraints: The nodes must be in the highway network if XY-coordinates are needed to calculate distance, the way type of the &ROUTE card segment on which the link appears must be exclusive guideway (W = 3), and the transit speed must be coded either on the &ROUTE card or on the &PARAM card.

Grade-separate fixed-guideway transit is rare (and special coding can usually be input with &ROUTE cards), so these coding conventions are not restrictive. In fact, coding routes on a fixed guideway is usually simpler than it is for transit on the normal highway network. Fixed guideways generally run parallel to street segments.

Figure 4 shows that, in coding the line, only &ROUTE card coding is used, because LRT vehicle speed can be directly estimated and coded and highway-network coordinates are accurate enough for distance estimates. If we assume that the guideway is straight between nodes, the LRT line is easily coded:

```
&ROUTE M = 6, L = 1, H = 5.0, W = 3, S = 40; SDT
  = 1.0; N = -141, -136, -129 &END.
&ROUTE M = 6, L = 1, W = 3, S = 30; SDT = 1.5;
  N = -129, -103, 122, 119, -102 &END.
```

Separate &ROUTE cards are used even though the way type does not change, due to changes in running speed (40-30 mph) and SDT (1.0-1.5 min) from the suburban to the urban part of the line. Each &ROUTE card implies a consistent level of service, whether it is the same way type, the same speed or SDT, or both for all links on the card.

Optional Transit-Link Data Cards

INET users will rarely need link data cards, but they may override or augment data in the highway network according to mode.

These cards can also describe fare structure. A fare code is used as an index to a fare table (in UPTS program UPATH) of modal link-specific fares, such as fare zone charges. These codes correspond to the modes coded on the card. A direction code indicates a two-way link whose impedance and fare code in the A-B direction are identical to those in the B-A direction.

Impact Estimates

INET generates energy and pollution indexes based on technology-specific impact rates. These technology codes are mode-specific indexes keyed to INET's table to energy and pollution impact rates for eight modes. The user may modify any or all of INET's rates with update cards. These rates (based on vehicle-crew miles) describe energy consumption and pollutant emission by mode and way type in INET Report 13. This simple flat-rate model ignores the effects of speed variation and deadheading.

In Figure 4, note that links 141 to 136, 136 to 129, and 129 to 103 show on the LRT route, even though they are not coded in the highway network. This is because they were coded as W = 3 on an &ROUTE card: Their distances will be computed from XY-coordinates.

INET writes a transit-network file for input to UPATH and ULOAD. Planners may perform the entire demand estimation and system evaluation of a system coded for INET by interfacing with the rest of UTPS. The network file for the LRT line, feeder lines, and supporting nontransit links could be produced for path finding and transit-impedance estimation with UPATH and UPSUM. These impedances could be used in a demand estimation that projects LRT patronage. Patronage estimates could then be assigned to the LRT binary network description with ULOAD and planning evaluations made with the outputs. Therefore, INET supports long-range system planning by using a coding scheme that makes it easy to represent both fixed-guideway alternatives and bus transit.

Example 5: Operations Planning

This example shows INET investigation of a new loop bus route to Utown. Figure 5 shows the route (M = 4, L = 30)--the Blue Loop--that provides coordinated transfers at node 103.

Arrival times are specified with the stop-time (ST) key word. ST overrides stop arrival times calculated by INET and displayed in INET Report 8 (Figure 3). The ST key word is a series of three numbers--a stop-node number followed by two 24-h clock times. The first clock time is that at which the left-to-right (reading the node sequence N) direction of the line passes that stop node, and second is that time at which the right-to-left direction of the line passes the same node. For

Figure 6. Route map for S.W. Mall bus (mode 5, line 11).

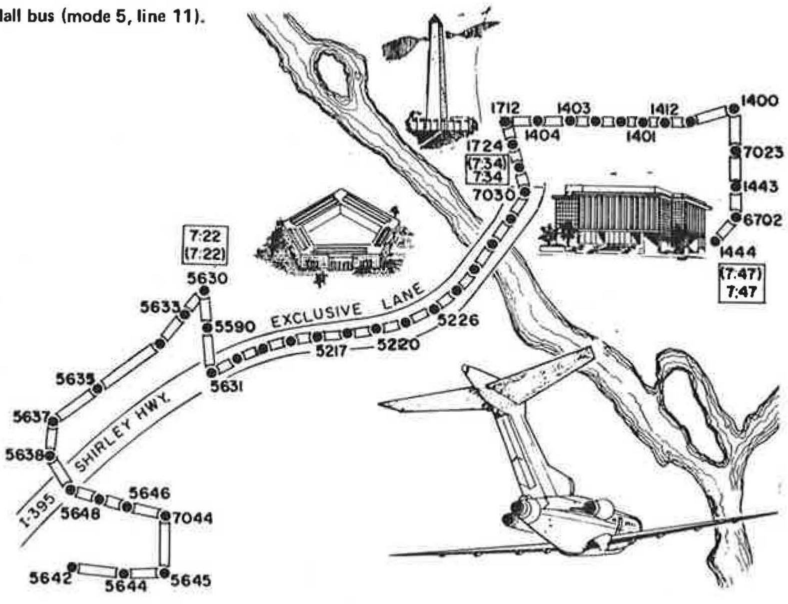
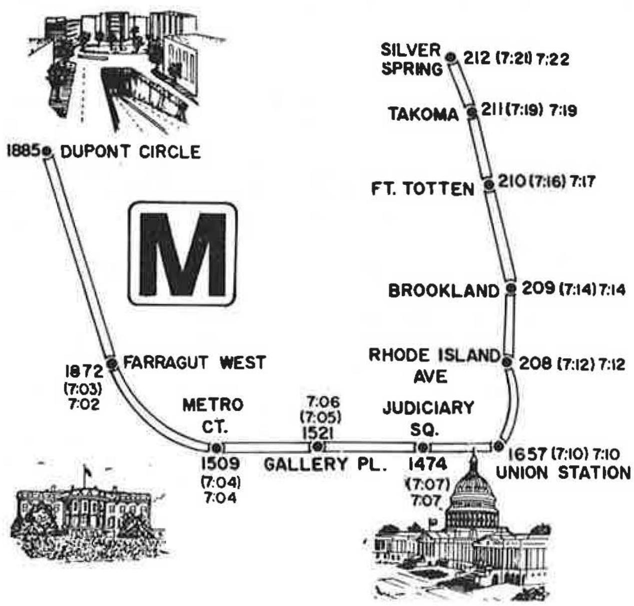


Figure 7. Route map for Metro Red-Line subway.



example, if for M = 4, L = 30 (Figure 5), stop node 103 had an outbound arrival at 8:00 a.m. and an inbound arrival at 8:30 a.m., the coding would be as follows:

```
&ROUTE M = 4, L = 30, H = 10; Period = (0700,
  0930);
N = 123, -103, 122, 128, -134, -135, 129, 123;
  ST = 103, 0800, 0830 &END.
```

PLANNING APPLICATIONS

Transit-System Planning

System planning usually looks toward a horizon 5-15 years away and reviews many alternatives. Since highway networks are usually coded for future years, many alternatives can be coded quickly and easily by INET with the network data base.

Another INET advantage for long-range planning is the use of highway automobile speed to determine transit speed. For all non-grade-separated transit, vehicle speed is a direct function of the speed of the surrounding automobile traffic. INET's computation of transit running speed has improved patronage estimates because service variables are more accurately assessed and reflect changes in the highway system. The more-refined calculations of running speed bring more-accurate resource estimates of vehicle crews, hours, and miles.

INET assists long-range planning with reports that distinguish and differentiate the characteristics of alternatives. In addition to the detailed line report (INET Report 8) used in the examples, other evaluative reports offer planners important guidance and insights before they begin expensive patronage forecasting.

The link report of number of transit vehicles per hour summarizes the volume on highway links by mode and way type. When modes share a line with the same way type, a summary line is produced that gives the number of vehicles per hour. This is useful in gauging the impact of transit vehicles on highway-system performance and might be important in a congested CBD.

The service summary report summarizes line miles, average miles per hour, and vehicle miles of travel (VMT) by way type and mode. It describes systemwide service for estimation of impact and cost and for documentation of differences among service alternatives.

The line summary report gives line information by mode from INET Report 8, as well as mode totals of various line statistics.

The resource-requirements report summarizes need for vehicle-crew units, hours, miles, and cost by company code and mode.

Finally, the impact summary report summarizes energy and pollution impacts by mode and way type.

Transit-Operations Planning

Transit-operations planning is short-range analysis (up to five years) of system modifications and improvements. Typically, alternatives are not capital intensive but involve route modifications, additions, or deletions.

Again, INET's simple coding scheme and use of the highway network let planners test a variety of proposed service changes. Since changes are usually perturbations of existing service, INET's acceptance of known service schedules is an important feature.

After an alternative is selected, INET will make a first attempt at scheduling and estimate the resources required.

INET is merely a first link to operations planning. A major effort is underway to provide the special software needed for scheduling and operations analysis. Already INET allows the transit system to be further analyzed in UTPS according to system accessibility (UMATRIX, UMODEL) and station requirements (USTOS) (4).

EXPERIENCE WITH INET

Is INET as quick and easy as is claimed? Can these simple default models produce accurate transit-link times? The answer is an unequivocal and heartening "yes." The reassurance comes from research and development at UMTA, where INET is used with real-world data from the Washington, D.C., Metropolitan Council of Governments.

The most-complicated case has been the development of a network data base for existing transit service in the Shirley Highway Corridor. Of modest size, it includes 167 zones, 2700 links, 50 transit routes, and 2 subway lines. The time spent in coding the Shirley Corridor network is divided as follows:

1. Add data to highway-network file where necessary and check out and debug to obtain complete highway-system description to satisfy INET's requirements. Time: 24 person hours.
2. Code and debug route cards. Time: 45 person hours.
3. Run INET, analyze transit speeds, and update cruising-speed and dwell-time tables where necessary. Time: 20 person hours.

Thus, coding takes less than 90 person hours by a young, inexperienced engineer; the second time, he or she should take about half that length of time. Coding a new alternative by adding to or deleting from existing service would require less than one day.

As for INET's accuracy, the results were amazing. Because an existing service was coded, INET's estimates of transit travel times could be compared with printed schedules. Every estimated run time was within 5 percent of the schedule, many were precisely on the mark, and most were within 1 min.

Figure 6 is a route map that shows a bus route through 44 nodes, the middle 14 of which are on the exclusive HOV lane on Shirley Highway (Interstate 395). The remaining 30 nodes are roughly split between the Virginia suburbs and downtown Washington. When time checks were made on entering and exiting the exclusive lane and at the downtown end of the line, at all three points INET times coincided exactly with the scheduled times.

Figure 7 depicts a Washington, D.C., Metro subway line. Comparing Metro schedules with INET output shows that no INET time is more than 1 min different from Metro's. These concurrences are the rule rather than the exception and reinforce the satisfaction with INET's performance.

Those who wish more information on the INET program may obtain a book on the subject from UMTA (5).

ACKNOWLEDGMENT

We acknowledge valuable ideas and comments from L. Quillian, G. Paules, S. Zimmerman, and T. Hillegass of UMTA; D. Gendell and R. Hall of FHWA; and R. Cody of Peat, Marwick, Mitchell and Company. We especially thank the programmers of INET, F. Dickson and R. Regen of the National Institute for Community Development. William Wolfe of G.S. Rutherford and Associates and Irene Engelhaupt of UMTA provided helpful editing skills.

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Publication of this paper sponsored by Committee on Public Transportation Planning and Development.

Value of Urban Transit Operating-Cost Models as Forecasting Tools

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Eight urban transit operating-cost models were reviewed to determine their value as forecasting tools. The models were found to have structural problems. In the average-daily-cost model and annual-cost model, the association of inputs with outputs was assumed to have a strong positive correlation. Case-study transit system data were used to test these relationships. The findings indicate that these two models were not reliable because strong positive