Dss2000-Decision Support System For Mobility Analysis

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Dss2000- A Decision Support System For Mobility Analysis.

INTRODUCTION

Hereby we propose a software system running under Windows as an integrated laboratory for vehicle mobility analysis. The system, DSS2000, can be viewed as a laboratory of decision simulation and support. In its project phase it allows to speedily perform, with the aid of a graphical interface containing the cartographic base of reference, simulations with respect to before-after analysis while providing an estimation of indicators of synthesis for the evaluation of alternative models. The system provides an estimation of the Origin to Destination (O-D) matrix of paths on the basis of statistical or observed data and to match those paths with the road network by way of a graph, utilizing two alternative assignment methods, the incremental method or the Method of Successive Averages, MSA In order to optimize the level of servicing in single arcs, the system permits the identification of the best path of circulation through an automatic procedure.

It is possible to graphically visualize the entity of traffic flows on the network and to estimate the level of atmospheric or acoustic pollution. The systems takes into account problems of verification and design on urban intersections with traffic lights (L.o.S., phasing, cycles of light changes, duration of green light), on the basis of an estimation of traffic flows, turns and the geometry of the intersection. For safety reasons an indicator weighted with respect to flows and conflict points of maneuvers is estimated for each intersection to identify black points. The advantages of the system are to be found in the simplicity of use inherent in the integration of graphic instruments with analytical instruments in a single software environment, as well as in the interactive elaboration of different scenarios arising from the comparison of different synthetic indicators, support instrument to the decision making process.

THE REPRESENTATION OF THE TRANSPORT OFFER

Importing The Cartographic Base

The first required operation is to import into the system the reference cartographic base necessary to build the graph of the routing offer. The cartographic base will have the original dimensions. Should those dimensions prove inadequate the metafile or bitmapped image can be increased or decreased using the + or – buttons. At each incremental or decremental step, the dimensions of the cartographic base are increased or decreased by 25%.

The graph of the road network and the results of trip simulations (flows) do not vary with respect to the cartographic scale. Hence the scale can be chosen by the user according to his own preference. The ratio of the real scale is easily preserved by measuring on the cartographic scale - in screen coordinates - two points with a known distance between them.

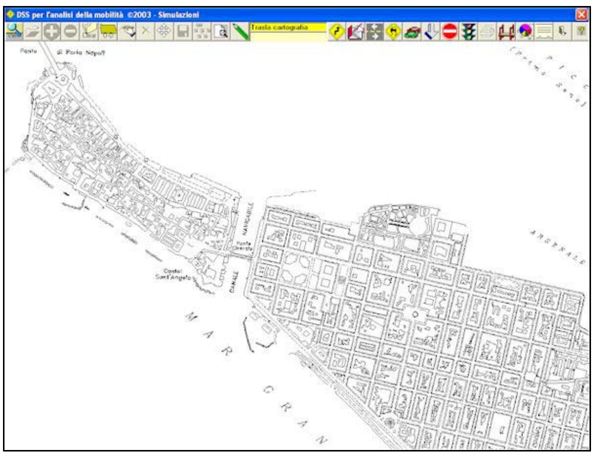

Figure 1: Example of cartographic base import

Network Construction

By network construction we mean the modeling of the road network with a reticular geometric structure which is the foundation of all the successive numerical computations pertaining to the simulations of offer and demand of mobility. The network construction can be achieved by drawing on the screen, on the cartographic quadrant just visualized, segments or broken lines (plotlines) coincident with the principal itineraries. The cartographic base can be mouse dragged to the required position. At each intersection of segments or lines a node is automatically assigned; the system itself takes care of node numbering.

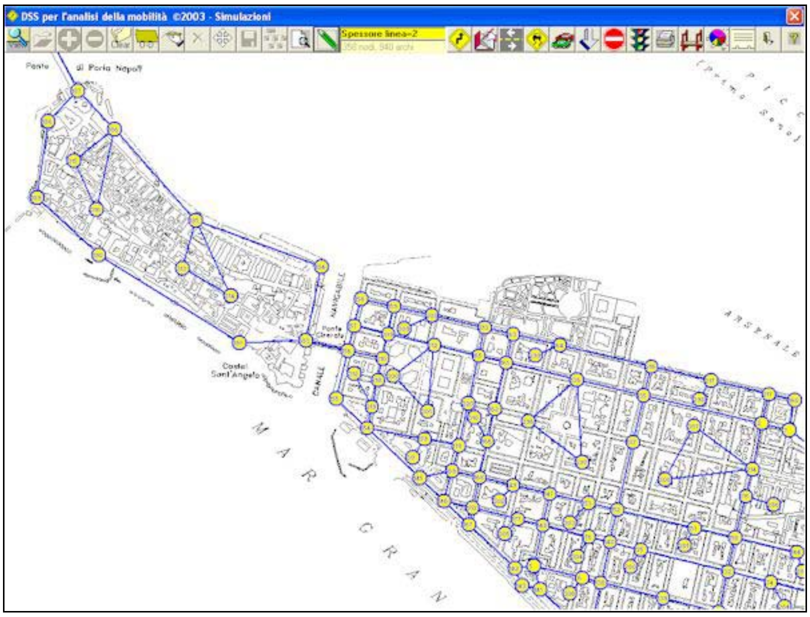

Figure 2: Example of graph construction for the road network

To represent permissible directions one can visualize the arcs with a single or a double line. Upon completion of the graph, the system performs a check on the complete connectivity of the graph (each node may be reached by any other node) as well as the calculation of the minimum paths.

Properties Of Arcs And Nodes

The following properties are defined for the arches.

Distance (in meters);
Access (0 no access, 1 permitted direction, -1 bridge or terminal arch)
Lane capacity (vehicles/hour)
Type of arch (local road/duration of parking, community road, highway, extra urban road, pedestrian path);
Road-name
Inclination (flat road, inclination<3%, median 3-5%, high 6-8%, steep >8%)
Tortuousity (straight line, low, median, high)
Parking (parallel, oblique, orthogonal)
Overtaking (permitted, prohibited)
Pedestrian paths (yes no with traffic lights, yes, no without traffic lights)
Intersections
Bus stops (yes, no in reserved lane, yes in no reserved lane)
Green light cycle (in seconds) (if in the final node of the arch an intersection with traffic light is present)
Traffic light cycle (seconds) (if in the final node of the arch an intersection with traffic light is present)
Buildings average height (meters)
Total number of accidents
Number of fatal accidents.

The nodes can be characterized thus:

Real nodes
Centroid nodes (with the relevant demographic attributes)

Parking nodes (free parking, time limit parking, paying parking with numbered spots

Figure 3: Form to define the properties of the arch.

Figure 4: Form to define the properties of the node.

Representing The Parking Offer

As we have already seen, it is possible to represent a node as a parking node (free parking, time limited and paying parking) to represent parking possibilities in a given area; such a node is then connected through a connecting arc to the centroid of the area. This parking node is linked with some real nodes of the network through other parking nodes; such arches are oriented exclusively from the real node towards the parking nodes. Each parking node of linked to the centroid nodes of adjacent areas through connecting arches (pedestrian arches), representative of the "disutility" the user feels in parking in an area different from his final destination. Obviously connecting arches will only connect the parking node to the centroid nodes of areas within walking distance. Furthermore the centroid nodes are linked to the initial nodes of parking nodes with connecting arcs oriented from the centroid to the real node.

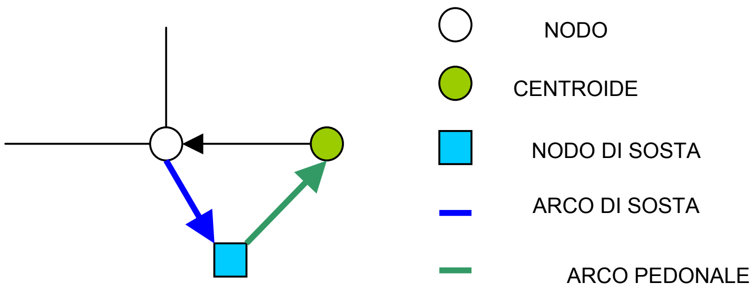

Figure 5: Schematization of the parking

Calculation Of Minimum Paths

Within a graph a route, a pedestrian walk or an itinerary is defined as a sequence of arcs in which the final node of each arc coincides with the initial node of the next node. A graph with only one path connecting a node 'i' with all the other nodes is called a node with root 'i'.

In transport networks only the paths which connect two nodes in which the trips begin and end are relevant: as we have seen, those nodes are called centroids. For a given graph with a fixed number of centroid nodes, all possible elementary paths with a centroid as initial end final node can be derived. Widely utilized algorithms for the search of paths with minimum cost or paths with minimum movement within any two centroid nodes, allow to calculate the trees with minimum cost with root in each origin node or destination node, and that for networks with arcs with positive costs; hence the minimum path connecting each destination node to the root node can be derived.

All the algorithms for the calculation of T*(0) (under graph "minimum cost tree with node 0 as root) are iterative in nature; at each iteration, a tree T(0) is identifiable which can be modified until it coincides with T*(0). The theory foundation of these algorithms is the Bellman theorem: it states that, given $X_{0,i}$ and $X_{0,j}$ the necessary costs to reach the nodes i and j from the root or with a unique.

path allowed from a generic tree with root 0, necessary and sufficient condition for a tree T(0) with root 0 to be a tree of minimum cost, T(0)=T*(0) is that for every two nodes i,j connected from an arc belonging to the graph in question, the condition :

$$X_{o,j} - X_{0,i} \le c_{ij}$$

be satisfied.

The variables $X_{0,i}$ for the tree of minimum cost are indicated with $Z_{o,i}$; they define the minimum cost to reach the generic node j from the root.

An ample class of algorithms for the search of minimum cost trees has a common structure; the starting point is an initial tree relative to a network modified by the introduction of imaginary arcs of infinite cost which connect the root or all the other nodes.

The initial tree made up by those imaginary branches is thus immediately identifiable and it does not introduce alterations in the calculation of T*(o): its arcs , of infinite cost, will be eliminated in the trees generated subsequently by the algorithm, except in the case of a disconnected network, that is to say if one or more nodes are not reachable by the node with root o. Each node of the network is labeled ei which characterize the state; or by a 'predecessor node' pi, that is to say the node (or arc) just preceding it in the generated tree. Knowledge of the predecessor nodes completely defines a tree in so far as it permits to build a 'backward' path from any node till the root. The vectors Z, p and e , all of dimension (n_Lx1), contain for each node of the graph the cost to reach the tree form the root, the predecessor node and the label respectively.

At each iteration a node of the network is examined and for every arc of the star outgoing from i, the condition $X_{o,j} - X_{o,l} < c_{i,j}$ is checked, where $Z_{o,j}$ and $Z_{o,i}$ are the current estimates of the minimum cost to reach those nodes from the root or utilizing the tree generated up to that iteration. If the generic arc (i,j) belonging to the star does not satisfy the condition $X_{o,j}$-$X_{o,i}$ <$c_{i,j}$ and therefore $Z_{o,j} > Z_{o,l} + c_{i,j}$, this implies that the path to reach j from the root in the current tree is certainly not the path of minimum cost; such a path is then replaced by the path connecting the root with the node I and arc (i,j); the cost $Z_{o,j}$ to reach j with such a path is updated by $Z_{o,j} = Z_{o,j} + c_{i,j}$. At the end of each iteration the nodes for wich path and cost were corrected, are added to a list, or buffer, L, from which the node to be examined by the next iteration is extracted.

The proposed software utilizes the Dijkstra algorithm.

In this algorithm the nodes in the list L are arranged in increasing order of cost; The element L(1) represents the node of minimum cost of all the nodes in L. At each iteration the first node that will never make the list again is examined: the nodes that will be introduced into the list during subsequent iterations will have a greater cost, by construction, of the one extracted for which the condition $X_{o,j}$ - $X_{o,i}$<$c_{i,j}$ will never be satisfied. In this sense the Dijkstra algorithm is "label setting" (LS) in nature in so far as at each step it definitely labels a node and therefore selects an arc in the tree of minimum paths.

THE TRANSPORT DEMAND

Inserting an OD external matrix

Only when the graph is drawn in a definite manner can the input of the mobility demand be derived. This stems from the fact that the node numbering is automatically performed and it is renewed ad each modification of the graph. The system allows an estimation of the OD matrix via gravitational models or the direct insertion of the OD displacement matrix. The OD matrix can be imported through the electronic sheet.

Estimating the OD matrix via gravitational models

In order to estimate the mobility demand (OD matrix of displacements), the number of the resident population in each area (origin) into which the territory will be divided is needed. Each area is represented by one or more nodes (centroids) into which the resident population is apportioned; the number of jobs available in different areas (displacements home-work), the number of clients attended (displacements home-service providing centers) etc can be considered as ‘attracting nodes’ (D destinations). Likewise the fluxes of day trippers, either coming in or going out or crossing over are estimated. Town data on day-trippers are provided by the National Institute for Statistics (ISTAT).

Data input is simplified and intuitive. Clicking with the mouse on a centroid node, the relative form for inputting or modifying data utilized in gravitational models for the estimation of the demand, are presented. The gravitational models available in DSS2000 are four: a constrained origin-destination; a constrained origin; a constrained destination and a constrained origin-destination. Calibration of gravitational models can be achieved by direct observations at the more significant nodes.

VEHICLE ROUTING INTO THE ROAD NETWORK

Arcs Cost Functions

The cost function of an arc is a relationship between the cost of the transport on the arc and the flows on the arcs of the network as well as the geometrical characteristics of the road which is represented by the arc itself. A cost function associated to the arc of an urban road is the sum of two terms: the time needed to complete the arc and the wait-time at the intersection. The first term keeps into account the time needed to travel over the road branch represented by the arc; the second one is the wait-time at the intersection point at the end of the arc itself.

The values inserted into the forms of the properties of arcs and nodes are used to derive the values of the cost functions associated to the arcs. The cost function cannot be directly defined into the arc form since this operation is performed at the same time as the assignment of the demand to the network.

The system utilizes the following functions:

- Equation as proposed by Festa and Nuzzolo (1990) to calculate the running time and HCM equation for the waiting time;

- BPR (Bureau of Public Roads);

- Doherty (utilizing Akcelik expression to determine the waiting time in the case of an upcoming saturation (flux/capacity) of the unit.

A separate treatise is needed to define cost functions associated to parking arcs and pedestrian arcs.

Festa and Nuzzolo (1990) and HCM (1994)

As we have seen the total time length to travel along the arc is given by the sum of two terms: the running time and the waiting time (at the intersection). The running time can be calculated as a function of the mean (commercial) speed:

$T_{i,r} = \frac{L_i}{V_i}$ where L_i is the arc length

The expression used to calculate Vi is that proposed by Festa and Nuzzolo

$$V_l = 31.1 + 2.8L_{u_l} - 1.2P_l - 12.8T_l^2 - 10.4D_l - 1.4INT - [0.000053 + 0.000123X]\left(\frac{f_l}{L_{u_l}}\right)^2$$

Where

Lu_l: road width in each direction, minus parking width, in meters;
P_l: median slope in percentage units (%);
T_l: tortuousness of the road in a 0 to 1 scale;
D_l: degree of circulation reduction in a 0 to1 scale;
INT: number of secondary intersections for each 1 km arc;
X: “shadow” variable; 1 in a non overtaking zone, 0 otherwise;
F_l: flow in the arc, vehicles/hour;

The expression utilized to determine the waiting time is the HCM formula (1991), obtained though different traffic simulations and valid for a generic access of an intersection with traffic lights

$$tw_l(f) = 0{,}45 \cdot \frac{C(1-\mu_i)^2}{1-\mu_i \cdot x_i} + 173 \cdot x_i^2 \cdot [(x_i - 1) + \sqrt{(x_i-1)^2 + \frac{0.16 \cdot x_i^2}{36 \cdot f_i}}$$

Where:

x_i : flow/(access capacity) ratio for the i-th arc;
C : the traffic light cycle in seconds;
μ_i : ratio green time/cycle time;

This expression yields acceptable results for values of Xi<1.2. The expression yielding Twi takes into account the green time/the cycle time ratio at the intersection as well as the degree of saturation of the arc itself. For the case of intersection without traffic lights, computational needs force us to assume $0<\mu<1$.

BPR (Bureau of Public Roads)

The most widely used cost functions (reflux curves) are of the type BPR (Bureau of Public Roads) according to which the cost of the displacement over an arc corresponds to the trip time. According to the BRP cost function, the trip time ti on the arc i depends on the flow fi intersecting the arc i compared with the maximum capacity Ci of the same arc, and on the time the user would need to travel over the arc in absence of flow (time To independent of flow).

The functional form is applied in different ways for urban arcs or extra urban arcs with pay tolls. In the latter case, the toll is transformed into time cost and considered as extra time on the arc.

In particular one will have :

- for urban arcs:

$$t_i = \frac{L_i}{V_{0i}} \cdot [1 + \alpha \left(\frac{f_i}{C_i}\right)^{\beta}$$

- for extra urban arcs with pay tolls:

$$t_i = \frac{L_i}{V_{0i}} + \alpha \left(\frac{f_i}{C_i}\right)^{\beta} + T_i$$

where:

L_i : length of the i-th arc;
V_{oi} : velocity for the ith arc with no traffic;
f_i : flow on the i-th arc;
α, β : parameters relative to the associated reflux curve;
T_i : extra time given by the formula Ti=Li*T* where T* is the unit cost in terms of toll time on the arc;

Doherty and Akcelik

The calculation of the running time is independent from the type either of the arc or the final node:

$$t_{ri} = 3{,}6 \cdot \frac{L_i}{V_i}$$

Where L_i is the length in meters of the arc and V_i is given by the expression:

$$V_i = V_{oi} - a \cdot \left(\frac{f_i}{L_{ui}}\right)^2$$

Where:

V_{oi} : velocity with zero flow;
a: 0.0001;
f_i: flow in vehicles per hour;
L_{ui}: real current length in meters

Any velocity V_i < 5 km will be set to 5 km.

For the determination of the waiting time, Doherty formula provides T_{wi} as

$$tw_l(f_l) = \frac{1}{2} T_C (1 - \mu_l)^2 + \frac{0.55}{\mu_l S_l} \frac{f_l}{\mu_l S_l - f_l} \quad \text{with } f_l \le \alpha \mu_l S_l$$

The first term is the delay for zero flow and is equal to the probability to arrive at the intersection with a red light (1-μ) for the mean waiting time if one arrives during a red light ½T_c(1-μ); the second term is the congestion produced delay which tends to infinity if the flow tends to the capacity μS.

For near capacity flows, Doherty formula loses meaning and computational convenience; to calculate the mean delay at intersections with traffic lights and flow near or over capacity,
Akcelik formula is used instead

$$tw_l = 0.5 T_c (1 - \mu_l) + 900T \left\{ x_l - 1 + \left[\left((x_l - 1)^2 + \frac{8(x_l - 0{,}5)}{\mu_l S_l T} \right) \right]^{\frac{1}{2}} \right\}$$

Where
$x_l = \frac{f_l}{\mu_l S_l}$ is the flow/capacity ratio.

Parking arcs and Pedestrian arcs

Cost functions for parking arcs and connecting walks (pedestrian arcs) are:

a) Parking arcs: the cost is expressed in the same way as for real arcs, i.e. in terms of travel time; those arcs are considered congested and the associated cost function takes the form:

$$t_i = t_{oi} \left[1 + \alpha \left(\frac{f_i}{k_i} \right)^{\beta} \right] + T_i + \gamma$$

where:

t_i : cost expressed in travel time of the parking arc i;
t_o : cost expressed in travel time for zero flow in the parking arc i;
f_i : flow on the parking arc I;
α e β : coefficients to be calibrated;
T_i : cost, expressed as travel time according to parking types (free parking, time limited parking, paying parking);
γ : coefficient to be calibrated (default value equals 5000 if the ratio f_i / k_i is greater or equal to 1,0 if it is <1);

This cost function expresses in time terms the "disutility" tied to the time lost in looking for a parking spot as well as the parking rate to be paid. The parking capacity k_i is set equal to the number of parking spots available in the parking node divided by number of parking arcs leading to the parking node.

The alpha and beta coefficients take the default values alpha=1, beta=2.4; this in consideration that the cost function has an almost constant value for f/k<1 and a high gradient for f/k>1.

b) Connecting arcs (pedestrian walks) : they are given a cost function , expressed as travel time, independent from the flows and linear function solely of the arc length.

$$t_i = \gamma L^{\alpha}$$

Where

t_i : travel time associated to the connecting arc i;
L_i :length of the connecting arc i;

Gamma and alpha are coefficients to be calibrated; in order to have a travel velocity of about 6-7 km/h and to represent the "disutility" perceived by the user of the increasing distance to cover, assume the values:

γ : 0.2 - 0.4,
α : 1.4-1.5

Assignment Models

Determined the minimum paths for every move O-D, the software allows to effect the assignment of demand to the net of transport according to two different models:

a) Incremental assignment;

b) Method of the successive averages (MSA);

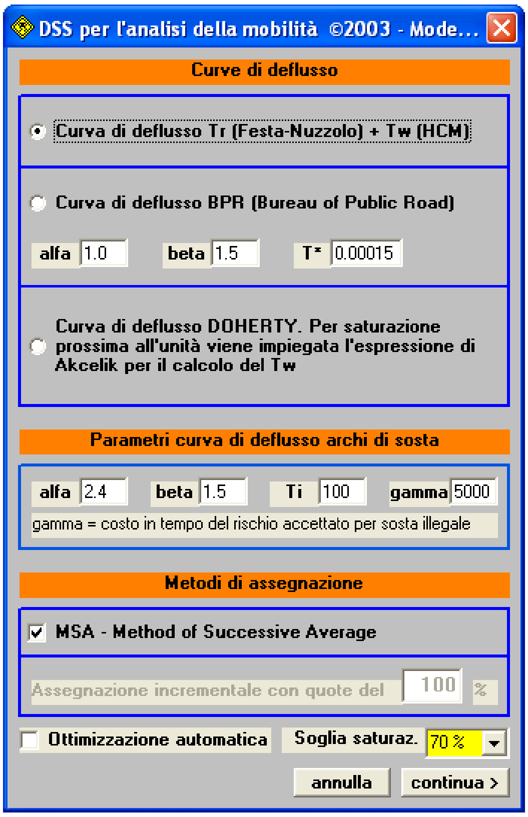

Figure 6: Form for the choice of the model of assignment to use and for the type of curves of outflow to be associated to the arcs.

Incremental Assignment

At the base of this model there is the hypothesis that the 'consumers' of the road-net perfectly know the costs of route and they are rational consumers. In such hypothesis is valid the principle of Wardrop according to which:

"if a run among a couple OD is used by one or more consumers the cost of such run is smaller or equal to the cost of all the other possible runs among the same couple OD"

The concept of base is that to subsequently assign shares of moves (preventively fixing the percentage of the moves to assign, fixing that is of the platoons or groups of consumers that stir from a same origin for a same destination) keeping in mind of the conditions of the net, different of time in time. Determined the least walks, it is assigned on every arc, a percentage of the flows substantially getting a configuration on the equivalent net to an assignment “All or nothing” with loads meeting places.

Before assigning the following share of the flows, it is determined the values of the functions of cost of arc come using the flows of arc previously assigned. The system calculates again the least walks, that can be different from the precedents, and to them another share is assigned. The algorithm continues with this scheme and the procedure finishes when it arrives to assign 100% of the flows.

MSA (Method of Successive Averages)

The method of successive averages (MSA) is an iterative assignment in which the flow current on an arc is calculated as a linear combination of the flow determined in a preceding iteration and of the flow auxiliary determined with an assignment ‘all or nothing’ in the current iteration. The value of the flows of arc of the n-exempts iteration V_a^n is determined through the following expression:

$$V_a^n = (1-\varphi)\cdot V^{n-1} + \varphi \cdot F_a^n$$

with :

$\varphi = \frac{1}{n}$ (n: number of the current iteration);

F_a^n : flows determined with an assignment ‘all or nothing’;

V^{n-1} : flow on the arc to the iteration n-1

The iterative procedure finishes when the difference among the values of the synthetic indicators (index of overflow mediate weighed on the flows and on the lengths of every arc, the middle speed weighed on the flows and on the distances) between two following iterations is inferior to 1%.

NETWORK AUTOMATIC OPTIMIZATION PROCEDURE

The implemented procedure, search, departing from an initial net, the excellent configuration (from the point of view of the circulation) of the road net, producing to every iteration a configuration better than that preceding. It conducts, as it appears evident, to determine a point of good place.

Function Objective

The function objective to minimize is the time of route among couples O-D weighed on the demand for couple OD:

$$F(A) = \min_A \frac{\sum_{od} d_{od} \cdot t_{od}(A)}{\sum_{od} d_{od}}$$

where:

A=A(s) : it points out a configuration of the net function of the senses of march (s)

D_{od} = flow of demand among the zone O and the zone D

T_{od} = middle time of route at equilibrium to approach from O to D in correspondence of the configuration of net A, function, among the other things, of the flows (f).

The middle times of route among couples O-D, are calculated with an assignment (incremental or MSA) of the O-D demand to the same configuration.

Search Methodology Of A Local Optimum

Effected an assignment of the flows of traffic to the net, it's calculated, for every arc, the degree of overflow weighed on the flows and on the length of the arcs gs_p given from:

$$gs_p = \frac{f}{C} \cdot f \cdot l$$

where:
gs_p = degree of overflow weighed on the flows and on the length of the arcs
C = capacity
f = flow on the arc
l = length of the arc

The software creates a list of arcs in decreasing order of gs_p. It individualizes the arcs for which the relationship f/C overcomes a preset value limit. It extracts the first arc of the list, "preserve" the drawn out arc and it is eliminated the inverse one, choosing so for every road the toward of route. Every time that an arc is eliminated the verification of connection effects; if the verification is negative the opposed toward of route is chosen. The scheme of the procedure is drawn in the following figure.

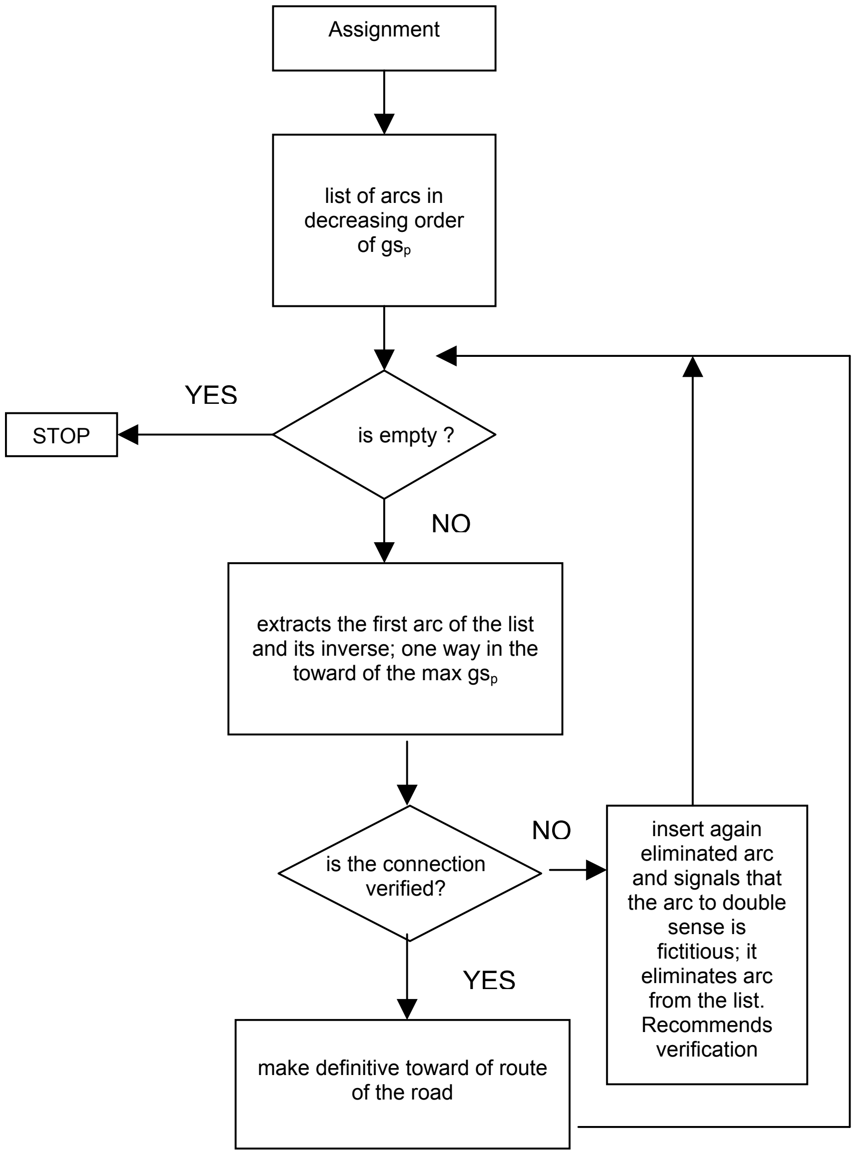

Figure 7: Logical flow of the procedure of optimization

During the start of the procedure of optimization it is possible to fix the value of the relationship f/C. Consider that, for the course that the functions of cost have, as value of default is assumed f/C = 0,7.

For every configuration gotten following the intervention, the objective value of the function and the difference of the same it is calculated in comparison to the initial value; if among these configurations exist one of them or more that have improved the objective value of the function in comparison to the precedent, as new configuration it is assumed that corresponding to the maximum improvement and a new iteration effects starts

It continues up to come to a configuration of net for which an any effected variation doesn't provoke an improvement of the scheme anymore. The convergence of the algorithm is insured from the structure of the same and from the fact that the number of solutions is finite; in fact, being the number of solutions finite and producing itself in every footstep a different solution, which corresponds an objective improvement of the function, in the worse one of the hypotheses all the solutions will be explored, but however a finite number of iterations will effect.

THE RESULTS

Auto Volumes

The result of the assignment is visualized on the cartographic base. The different coloration, (from the celestial clear to the blue one) representative of the different degree of overflow of every arc and the different thickness, representative of the auto-volumes on every arc, allows the planner to have an immediate perception of the flows and the congestion on the whole net. Besides it is possible to visualize the attributes of the arcs and the numerical consistence of the calculated flows.

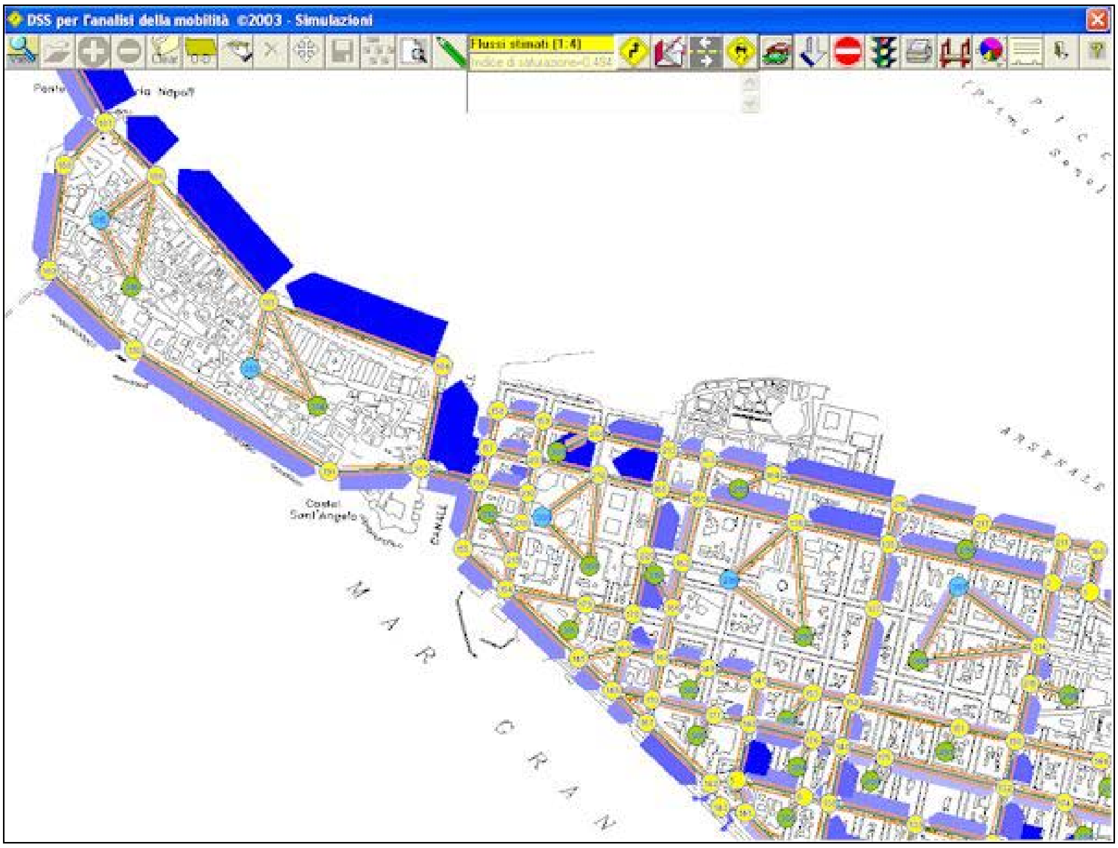

Figure 8: The graphic representation of the flows

graflux.txt - Blocco note

File Modifica Formato Visualizza ?

ATTRIBUTI DEGLI ARCHI E FLUSSI CALCOLATI (Assegnazione incrementale con curve di deflusso BPR)

Nodo I	Nodo J	Bridge e D.A.	Distanza in mt	T running in sec	T wait in sec	Portata	Capacità	Vm Km/h	CO(g/h)	Leq(db)	Toponimo
1	160		106.2	11.5	0.0	397	1800	33.3	538	90.1	-------
3	4		61.4	11.0	0.0	1051	1800	20.1	1292	99.3	-------
3	274		119.4	21.7	0.0	1258	1800	19.8	3059	101.1	-------
4	1		253.1	27.5	0.0	1051	1800	33.2	3411	100.0	-------
5	142		66.4	6.6	0.0	32	1800	36.1	25	64.6	-------
6	306		69.7	7.5	0.0	127	1800	33.5	111	78.5	-------
7	8		145.3	16.4	0.0	163	1800	31.9	314	80.9	-------
8	7		145.3	11.6	0.0	366	1800	45.1	517	90.0	-------
8	9		126.2	11.4	0.0	348	1800	39.8	477	89.1	-------
9	8		126.2	10.2	0.0	298	1800	44.6	369	87.8	-------
10	3		78.1	16.1	0.0	2280	1800	17.5	4062	107.0	-------
10	9		174.0	35.5	0.0	329	1800	17.7	1290	87.3	-------
11	10		100.9	21.8	0.0	2609	1800	16.6	6230	108.3	-------
11	325		98.3	21.3	0.0	191	1800	16.6	448	81.7	-------
12	11		114.1	12.6	0.0	2752	1800	32.7	4081	109.8	-------
12	17		283.9	29.1	0.0	189	1800	35.1	653	82.6	-------
15	272		122.2	41.8	0.0	208	1800	10.5	915	82.2	-------

Figure 9: Attributes of the arcs and calculated flows

It is possible, besides, to visualize in a spreadsheet (MS Excel) all the characteristics (flows, times of route, etc.) related to the least walk that unites two nodes chosen by the consumer selecting with the mouse the initial node and the final node of the run.

Synthetic Indicators For The Control Of Alternatives

The software allows to calculate at the end of every assignment some synthetic indicators (Montella, Gallo 1997) profits for the comparison of the alternatives.

a) index of over-flow weighed on the flows and on the lengths Lij of every arc ij given by the following relationship:

$$I_S = \frac{\sum_{ij} \frac{f_{ij}}{C_{ij}} \cdot f_{ij} \cdot L_{ij}}{\sum_{ij} f_{ij} \cdot L_{ij}}$$

where: fij = flow on the arc ij, Lij = length of the arc, Cij = capacity of the arc ij.

b) middle speed weighed on the flows and on the distances of every arc given by the following relationship:

$$V_C = \frac{\sum_{ij} V_{ij} f_{ij} L_{ij}}{\sum_{ij} f_{ij} L_{ij}}$$

where: Vij = speed commercial average on the arc ij.

c) Vehicles-Km, given from:

$Veic - Km = \sum_{ij \in ar} f_{ij} \cdot L_{ij}$, where ar is the whole the real arcs of the net.

d) Vehicles-h, given from:

$$Veic - h = \sum_{ij \in ar} f_{ij} \cdot T_{ij}$$

URBAN INTERSECTION WITH TRAFFIC LIGHTS

Traffic Light Regulations

Traffic light regulation is the technique usually adopted for the control of the intersections characterized by remarkable flows, such that is not to allow the adoption of a based regulation on the usual rules of priority (precedence to the right) or on a fixed system of signs (stop signal or “to give way”).

The principal function of the traffic light is to discipline the maneuvers that happen to the intersection, determining the periodical arrest of every tide, in such way to allow the passage of all the vehicles and to avoid, if possible, trajectories of conflict among the vehicles or between vehicles and pedestrian flows: in this way it increases the safety of the intersection and reduces the delays to it connected. DSS2000 allows to face both problems of verification and project of a traffic light intersection. The problem of verification fundamentally consists in the determination of the level of service of the intersection. The problems of project are, generally, partial problems : with some characteristics of the intersection we want to plan some others.

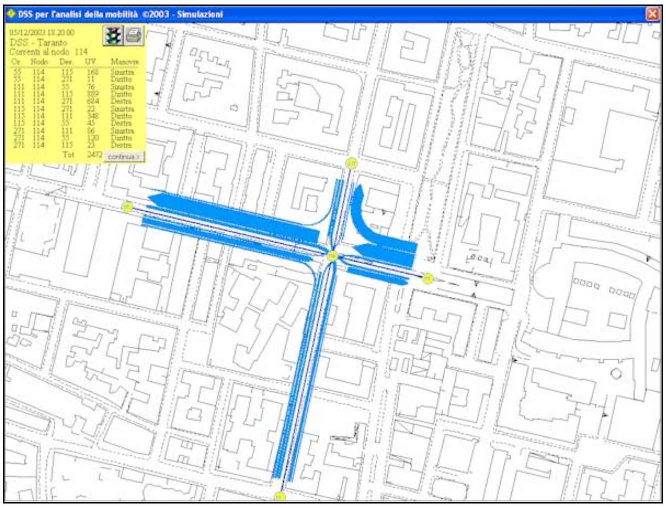

Figure 10: Graphic representation of the manoeuvres of turn to the intersection

The software allows, notes the geometry of the intersection and flows, to plan the characteristics of the traffic light.

- cycle

- phases

- times of green

It is possible to determine the saturation flow for every access of the intersection through the "English Method", to calculate the least cycle, the excellent cycle (according to Webster) and the times of green and to determine the level of service of the intersection.

Figure 11: Form for the study of the intersection: the program elaborates in automatic way all the characteristics of the intersection (phases, cycle, time of green)

Level Of Service Determination

The level of service (LoS) for urban intersection with traffic light is defined in terms of "delay of stop mediate for vehicle." The delay is in fact a measure of the "discomfort", of the consumption of fuel and the time employed in the move. The criterions to define the level of service found more precisely, on the analysis of the middle delay of stop effected for period of 15 mins. The delay depends on many factors among which the quantity of the flow, the length of the cycle, the relationship v/C.

The level of service of an intersection with traffic light is determined on the base of the calculation of the "critical movements": for critical movement we mean the most greater among the auto-volumes of every phase (having n phases, the critical movements will be n). In the following chart the maximum sums of movements critical profits are brought to the determination of the level of service.

Chart 1-Evaluation of the L.o.S. of the intersection with traffic light

	2 phases	3	4 or more	L.o.S.
Maximum sums of critical movements	1000	950	900	A
	1200	1140	1080	B
	1400	1340	1270	C
	1600	1530	1460	D
	1800	1720	1650	E
	Not applicable			F

Safety At Intersections

For every intersection is esteemed an indicative PN as function of the current F_m and of the numerousness of the points of conflict owed to the maneuvers of turn (points of convergence PC_i, points of divergence PD_j, points of intersection PI_k), with the purpose to assign 'ex-ante' a score of dangerousness (among 0 and 1) to the intersection.

it is had therefore :

$$PN = 0.6 \sum F_i \cdot PC_i + 0.3 \sum F_j \cdot PD_i + \sum F_k \cdot PI_K)$$

Such indicator is normalized among 0 and 1 setting:

$$PN' = (PN - PN_{min}) / (PN_{max} - PN_{min})$$

being PN_{min} and PN_{max} respectively the least and maximum value among all the calculated PN.

ENVIRONMENTAL IMPACT OF TRAFFIC

The used models of simulation refer to the CO emissions and to acoustic emissions. The formulations used in the system are type simplified for getting a greater facility of management. The CO emissions, grams for arc, are appraised through a model that keeps in mind of the vehicular flows, of the speed of route of the arc in congested situations and of its length. With different model it is possible to calculate the sonorous pressure in proximity of the roads instead. Such model keeps in mind of the entity of the flows, of some distance of the receptor and the middle speed of route of the arc. Both the models of simulation of the impacts keep in mind of an atmospheric condition "average" and they neglect phenomenons type "effects canyon" or climatic variations produced by the particular environmental conditions.

CO Emissions

CO emissions are appraised on every arc (fig.9) with a model whose formulation is the following:

$$e = 300 \times VELC^{-0.9} \text{ (gr/veic x Km)}$$

from which is possible to draw the hourly total emission for arc

$$E = e \times L_a \times VOL \text{ (gr di CO/ora)}$$

where:

VELC = speed of route on the arc;
L_a = length of the arc in Km;
VOL = vehicular flows (peak hour);

Acoustic Emissions

The evaluation of the acoustic emissions are esteemed on every arc (fig.9) through a model whose mathematical formulation is the following:

Leq = 49,5 + 10,2*log VOLs-13,9 logs D + 0,21 VELCs [db(A)]

Where:

Leq = acoustic emission for arc;
VOL = vehicular flows (peak hour);
D = distance of the sonorous receptor, valued in 5,00 mt;
VELC = speed of route on the arc;

DSS2000 SYSTEM VALIDATION

To verify the correctness of the adopted models proceeds to a comparison among a case of study performed with DSS2000 (reported to the study of the private mobility in the city of Taranto), and the same ‘scenario’ realized with EMME/2, one of the most diffused softwares in the sector of the planning of the transports, select as reference for its sturdiness and algorithmic validity. The comparison has been effected, gives the net and the matrix O/D, among an assignment performed with DSS2000 (incremental assignment with curves of outflow type BPR) and an assignment performed with EMME/2 using the same curves of outflow.

Figure 12: assignment with Emme/2

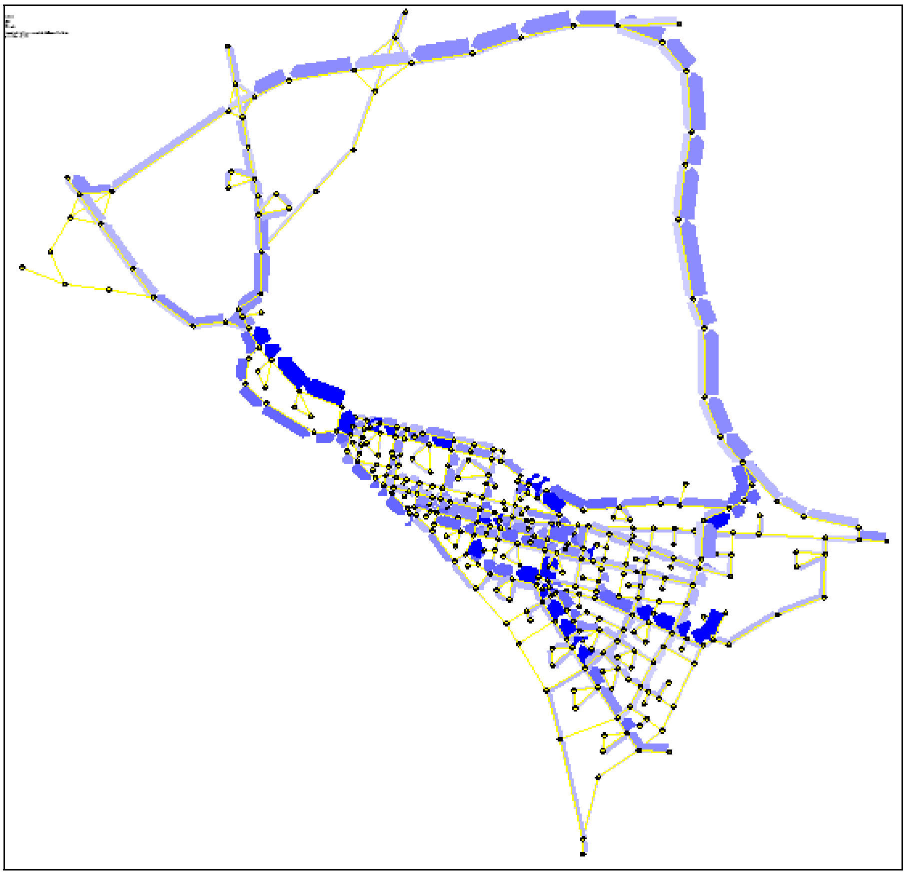

Figure 13: assignment with DSS2000

After the assignment they are results loaded 729 arcs in EMME/2 and 703 in DSS2000 with a 3% discard. Between EMME/2 and DSS2000 they are in common loaded results 703 arcs (that is the 100% of the loaded arcs in DSS2000). The coefficient of correlation R among the flows of arc calculated with DSS2000 and the flows of arc calculated with EMME/2 results of +0.96.

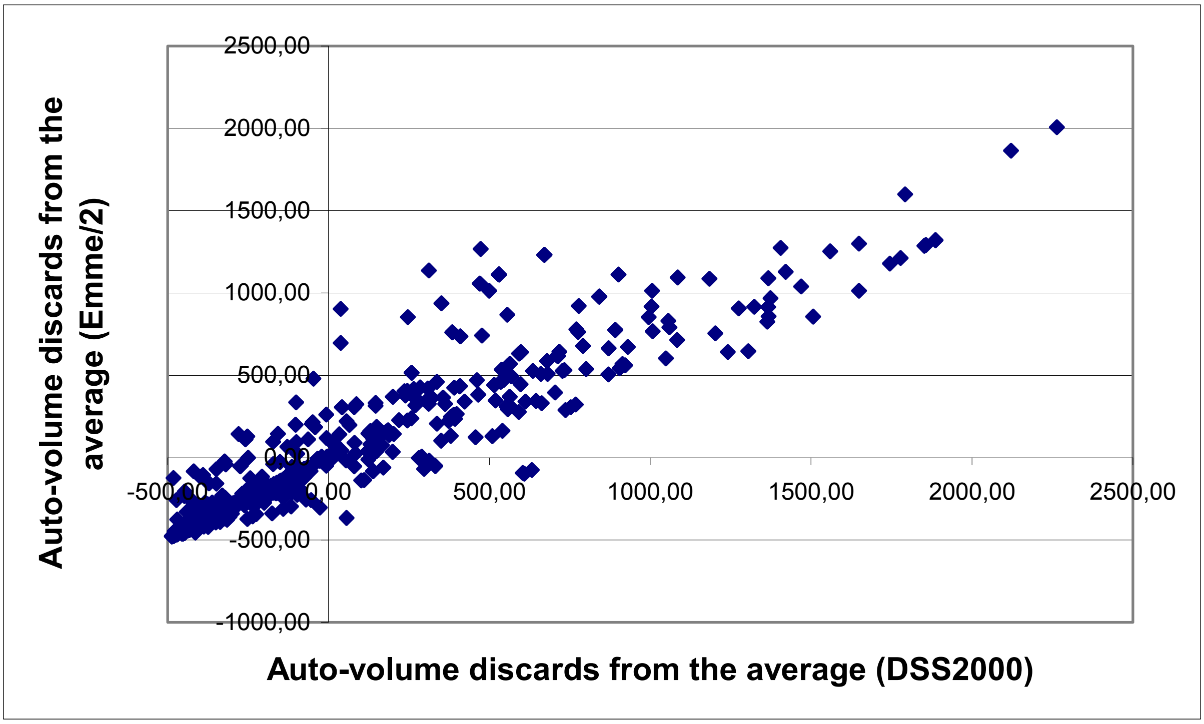

Figure 14: The coefficient of correlation R among the flows of arc calculated with DSS2000 and the flows of arc calculated with EMME/2 results of +0.96

CONCLUSIONS

DSS2000 can be concerned as an effective tool of analysis of the mobility, allowing with an interface friendly, interactive elaborations more scenarios with the relative synthetic indicators from whose comparison is possible to make to emerge optimized decisions. Besides, DSS2000 has been implemented keeping in mind in particular way of the contained methodological indications in the Directives of the Office of the LLs. PP. for the editing, adoption and realization of the Urban Plans of the Traffic (G.U. June 24 th 1995).

DSS2000 can finally, be used for doing, in presence of new installations, forecasts speditive of impact on the mobility, to simulate “ex-ante” corrective measures that concern the parking, to foresee modifications of the question it connected to occasional changes of the offer (jobs of road maintenance) and to be able to correct the traffic light regulation on the alternative runs, to optimize the schemes of circulation.

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BIBLIOGRAPHY

Andronico A., Bozzo U., (1975), *Esercitazioni di programmazione*, Zanichelli, Bologna.

Bowyer A., Woodwark J., (1983), *A programmer’s geometry*, Butterworths, England.

Cascetta E., (1998), *Teoria e metodi dell’ingegneria dei sistemi di trasporto*, Utet, Torino.

Cascetta E., Montella B. (1998), *Metodologie per la redazione e la gestione dei piani urbani del traffico e della mobilità*, Franco Angeli, Milano.

Ferrari P., Giannini F., (1977), *Geometria e progetto di strade*, vol. I, ISEDI, Milano.

Fuggetta A., Ghezzi C., (1991), *Ingegneria del software*, Mondadori, Milano.

Daboni L., Malsani P., (1975), *Ricerca operativa*, Zanichelli, Bologna.

Da Rios G., (1981), *Intersezioni Stradali*, Clup, Milano.

Da Rios G., Rinelli S., (1991), *Semafori*, CittàStudi, Milano.

Lee C., (1973), *Models in planning*, Pergamon Press, Oxford.

Lowry I., (1972), *Modello di una metropoli*, Guida, Napoli.

Montella B., Gallo M., (1997), *Come valutare la soluzione ottimale per un piano urbano* , *Onda Verde*, n. 47, 46-49.

Ore O., (1972), *I grafi e le loro applicazioni*, Zanichelli, Bologna.

Stavely Allan M., (1999), *Toward Zero-Defect Programming*, Addison-Wesley, Amsterdam.

Yang Q., (1997), *A simulation laboratory for evaluation of dynamic traffic management systems*, Department of Civil and Environmental Engineering, MIT.

Weiss M., (1999), *Data structures & algorithm analysis in C++*, Addison-Wesley, Amsterdam.

Cascetta E. e Montella B., Metodologie per la redazione e la gestione dei piani urbani del traffico e della mobilità, Ed. Franco Angeli , CNR – PFT2.

Montella B. , (1996), Pianificazione e controllo del traffico urbano: modelli e metodi , CUEN

Giulio E. Cantarella e Demetrio C. Festa, (1998), *Modelli e metodi per l'ingegneria del traffico* , Laboratorio di analisi dei sistemi di trasporto – Reggio Calabria, Collana Trasporti, Ed. Franco Angeli

E. Cascetta, (1998), Teoria e metodi dell'ingegneria dei sistemi di trasporto, UTET

De Luca M. e Astarita V., *I piani urbani del traffico*, Società italiana dei docenti di trasporti, Collana Trasporti, Ed. Franco Angeli

Morici I., *Regolazione semaforica, tecniche di base* , AIIT – Quaderni di tecnica del traffico e dei trasporti, Ed. Fratelli Palombi Editori

Bell M.G.H., Inaudi D., (1994) *Controllo semaforico e gestione integrata del traffico urbano*, Sistemi di Trasporto, CSST, 2 /;

C.N.R., (1992), *Norme sull'arredo funzionale delle strade urbane*, Bollettino Ufficiale C.N.R., n°150 /;

Callini D., (1997), *Gli itinerari a priorità*, Le Strade, Maggio;

Cantarella G.E., Sforza A. (1994), Modelli e metodi di regolazione semaforica per la gestione del traffico urbano, Sistemi di Trasporto, CSST, n°2;

D'Armini P., (1974), *Regolazione della circolazione*, Facoltà di Ingegneria, Università di Roma;

Festa D.C., Tassone R., (1992), Il flusso di saturazione delle intersezioni semaforizzate nelle aree urbane di medie dimensioni, in Cascetta E., Salerno G. (a cura di), "Modelli e metodi per l'analisi ed il controllo delle reti di trasporto", Editore Franco Angeli;

Guerci C.M., (1996),Telecomunicazioni e informatica per i trasporti - tecnologia e mercato al 2005, Editrice Il Mulino;

Guerra C., Mussone L., (1995), Linee evolutive della regolazione semaforica nel controllo del traffico urbano, Trasporti e Trazione, n°1;

Hunt P.B., Robertson D.I., Bretherton R.D., Winton R.J., (1981), *SCOOT - A Traffic Responsive Method of Coordinating Signals*, TRRL Laboratory Report H. 1014;

Istitution of Highways and Transportation, (1987) *Roads and Traffic in Urban Areas*, London;

Kimber R.M., Mc Donald M., Hounsell N.B., (1986), *The prediction of saturation flows for road junctions controlled by traffic signals*. Research Report 67, Transport and Road Research Laboratory (TRRL);

R. Cofano, commenti di G. Acquaviva *, Taranto Pura* , Schena Editore

EMME/2, *User's Manual* – INRO

M. Pezzagno, Strade urbane in Europa: interventi a favore della sicurezza nei centri urbani residenziali, Quaderni di sintesi ASM Brescia

G. Maternini, (1998), Le ricerche sull'incidentalità stradale per la realizzazione e la verifica dei Piani Urbani del Traffico, in M. De Luca e V. Astarita (a cura di), I Piani Urbani del Traffico, Editore Franco Angeli;

M. Lupi, (1998), Determinazione del livello di servizio ad un'intersezione semaforizzata: alcune osservazioni sulla modellizzazione del ritardo, in M. De Luca e V. Astarita (a cura di), I Piani Urbani del Traffico, Editore Franco Angeli;

Torrieri V. e Gatuso D., (1998), Analisi sperimentale di modelli di assegnazione alle reti stradali urbane in rapporto ad ipotesi di riclassificazione viaria, in M. De Luca e V. Astarita (a cura di), I Piani Urbani del Traffico, Editore Franco Angeli;