Route management in Safer Transportation Network Planning

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Safety principles, planning framework and library information

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Summary

This report is one in a series of publications, used in the development of the network planning tool ‘Safer Transportation Network Planning’ (Safer-TNP). The publications were used to guide the development of planning structures, diagnostic tools, planning recommendations, and research information in the computer tool Safer-TNP.
Safer-TNP is a design tool that guides network planners in designing safe transportation networks (or improving safety of existing transportation networks). It provides the practitioner with diagnostic tools, and guiding information. At the moment of publication of this report, Safer-TNP is still being developed.
Besides this ‘Route management report’, the following reports have been published in this series:

- Access management in Safer Transportation Network Planning (Hummel, 2001a);
- Land use planning in Safer Transportation Network Planning (Hummel, 2001b);
- Intersection planning in Safer Transportation Network Planning (Hummel, 2001c).

The information in this report will be used to guide the structure and the programming of different parts of the Safer-TNP tool with respect to route management. Described is, in a step-by-step procedure, what information is needed, and in what way the information should be processed. In the last chapter of the report, background information is provided to give users of the tool guiding information. Because of the specific purpose of this report, its structure and style deviate somewhat from regular research reports. Because the different chapters are used in different stages of the development of Safer-TNP, there is some repetition of information. Furthermore, the information is written in telegraphic style, to simplify the electronic packaging of information in Safer-TNP.

In this report, a method is described to persuade road users to use the safest possible routes in the network. A diagnostic tool is described to analyse the route-choice for the most important origin-destination relations in the network. If the chosen routes are not the safest (or most functional) routes in the network, techniques are described to redirect traffic by either increasing travel time on the undesired routes or by decreasing travel times on the desired routes.

Contents

1. Background

1.1. Definition

- Route management is the practice of:
  - persuading road users to use the routes as intended by the designer of the network.

- The aim of route management is:
  - to match the use of the roads and routes in a network with the function of those roads and routes.
  - to provide the roads and routes with one (and preferably not more than one) of the three functions: flow function, distributor function and local access function.

1.2. Scope

Route management techniques can be applied in both existing and in newly planned situations.

- Existing:
  If the actual use of roads and routes does not conform to the function of those roads and routes in the network, route management techniques can be applied to redirect the traffic to the intended roads and routes.
- New:
  Route management can be used to support the functional classification of the network. The function is not to redirect traffic, but to improve recognition.

1.3. Scale

- Route management techniques can be applied to the following two scales of network planning:
  1. A regional network of roads connecting a number of communities.
  2. A network in a community or urban area.

1.4. Potential benefits

- Route management supports compliance with the functional classification of the network. Route management can thus intensify or improve the benefits of the functional classification:
  - Exposure to risk:
    In an efficient and functional network, routes are direct (no detours), and the shortest routes coincide with the safest routes, thus reducing overall travel and exposure to risk.
  - Conflicts:
    - reduction of conflicts between continuously through-moving traffic and discontinuously moving access-related traffic.
    - reduction of conflicts between fast moving vehicles and vulnerable road users.
    - reduction of conflicts caused by route seeking and manoeuvre obscurity or complexity.

- Capacity:
  The part of the network with an exclusive flow function generally guarantees a continuous and uninterrupted throughput.
- Environment:
  A continuously moving traffic stream causes less environmental damage than a congested or frequently stopping traffic stream.
- Quality of land use activities:
  Roads with an exclusive access function have ideal conditions for high-quality land use activities, such as in residential, recreational and industrial areas.

2. Safety principles

- The overall Transportation Network Planning approach is based on a framework of safety planning principles (i.e. as discussed in more detail in the 'Learn' Module).

  - **Minimize Exposure**
    - *Promote efficient land use.*
    - Provide efficient networks where the shortest/ quickest routes coincide with the safest routes.
    - *Promote alternative modes.*

  - **Minimize Risk**
    - Promote functionality, by preventing unintended use of each road.
    - Provide homogeneity, by preventing large differences in vehicle speed, mass, and direction of movement.
    - Provide predictability, thus preventing uncertainty amongst road users by enhancing the predictability of the road's course, and enabling the behaviour of other road users to be anticipated.

  - ***Minimize Consequences***
    - *Reduce speeds.*
    - *Provide a forgiving roadside.*
    - *Protect vulnerable road users.*

- This chapter discusses the interaction between these principles and route management. The principles printed in italic are not considered to be relevant to route management and will therefore not be addressed in this chapter.

2.1. Exposure

Efficient networks

- In an efficient network, exposure is minimized by:
  - trips that are short and direct
  - the shortest/ quickest routes in a network are also the safest.
- Route management can improve network efficiency:
  - by supporting the network classification (clear guidance improves recognizability)
  - by redirecting traffic if the network efficiency is not optimal (shortest or quickest is not safest).

2.2. Risk

Functionality

- Route management can prevent unintended use of each road, by directing or redirecting traffic to the intended roads and routes (use of road in accordance with function of road).
- The use of rat runs can be discouraged by turning restrictions or increasing travel times on the rat runs by traffic calming measures.

- The use of the intended routes can be encouraged by reducing travel times on these routes.

Homogeneity

- Route management can stimulate road users to use road networks as intended, causing a more homogenous use of the different elements of the network (e.g. only through-traffic on arterials). Friction and differences in speed and in directions of moving are reduced.

3. Planning framework

3.1. Preparatory work

The following information should be available in order to be able to undertake route management:

- Map
- Origins and destinations (schematic)
- Road and intersection information:
  - functional category of links and intersections
  - road form and intersection form
  - priority directions on priority intersections
  - speed limits
  - capacity of links and intersections
  - access density
  - level of service for intersections.
- Traffic information:
  - volumes
  - presence of different types of road users
  - actual level of safety.

3.2. Understand the area

Table 1 shows the actions which have to be taken to give an understanding of the design area. These actions have to be taken by the user of STNP (1) and by the tool STNP itself, in the form of computing (2), and showing information on the map (3) and in the right-side column (4) on the screen.

Action 2.2/ 2.6/ 2.10:

Total length of route	.....km
of which	.....km on rural freeway
	.....km on rural expressway
	.....km on rural major distributor
	.....km on rural minor distributor
	.....km on rural local road
	.....km on urban freeway
	.....km on urban expressway
	.....km on urban major distributor
	.....km on urban minor distributor
	.....km on urban local road

Leave out categories with length = 0

Action 2.9:

The method to calculate travel times on routes is described in *Appendix 1* ‘Calculation of travel times’.

1. Action User	2. Action STNP	3. View on Map	4. View in right-side column
1.1. Plot Origin (O) and Destination (D) on map		3.1. Plot Origin, Destination, + desire line (Colour 1)	
	2.1. Calculate distance between O and D as crow flies		
1.2. Indicate desired route(s) between O and D by selecting links		3.2. Plot desired route(s) (Colour 2...)	
	2.2. Calculate length of desired route (total and specified for each road class) (*)		
	2.3. Calculate travel time on desired route(s)		
	2.4. Calculate actual and predicted accidents on desired route(s)		
	2.5. Determine shortest route (distance) between O-D	3.3. Plot shortest route (Colour 3)	
	2.6. Calculate length of shortest route (total and specified for each road class)		
	2.7. Calculate travel time on shortest route		
	2.8. Calculate actual and predicted accidents on shortest route		
	2.9. Determine fastest route (travel time) between O-D (*)	3.4. Plot fastest route (Colour 4)	
	2.10. Calculate length of fastest route (total and specified for each road class)		
	2.11. Calculate travel time on fastest route		
	2.12. Calculate actual and predicted accidents on fastest route		
	2.13 Calculate difference between fastest route and desired route 1 -		
			4.1. Fastest route = Desired route? (*)

(*) See comments in text.

Table 1. *Actions which have to be taken to give an understanding of the design area. Actions should be taken by the user of STNP (1) and by the tool STNP itself, in the form of computing (2), and showing information on the map (3) and in the right-side column (4) on the screen.*

Action 4.1:

Does the desired route coincide with fastest route?

Yes: "Desired route .... appears to be the fastest route in the network between the given Origin and Destination, indicating road users will probably use this route".

No: "Desired route ....does not coincide with the fastest route in the network between the given Origin and Destination. The fastest route is ....sec. shorter than desired route...."

3.3. Diagnostics

Table 2 shows the actions which have to be taken to diagnose the road network safety. These actions have to be taken by the user of STNP (1) and by the tool STNP itself, in the form of computing (2) and showing information on the map (3) and in the right-side column (4) on the screen.

Action 2.14:

Appendix 2, 'Route Factor', describes that a route factors higher than 1,6 can be an indication for inefficient routes. Pilot studies have to prove whether this threshold value of 1,6 is useable.

Action 2.17:

After the start of the trip, cars should use higher category roads as soon as possible, and should preferably use the highest category as much as possible.
In a functional route, traffic should only use local roads at the beginning or at the end of a trip. The use of local roads on other sections of the route than beginning or end can be described as rat runs.

E.g.: "Local - local - distributor - expressway - distributor - local" is alright. "Local - distributor - local - ...." or ".... - distributor - local - distributor - local" is not desirable.

The beginning and the end of a trip can be local. If apart from beginning and end a higher category is followed by a local road, this should be detected and indicated to the user.

Action 2.20:

An example of a time-path diagram is shown under the explanation of Action 4.19 (see *Figure 1*).
Time-path diagrams not only show immediately which route is the most functional route, but can also show deficiencies in routes (like large delays, frequently changing of road category, too many intersections etc.).

1. Action user	2. Action STNP	3. View on map	4. View in right-side column
		3.5. O+D, desire line, desired route(s), fastest route, shortest route	4.2. Fact sheet for desired route(s), fastest route, and shortest route (*)
1.3. Choose route(s) to analyse in more detail (tick routes as shown on map)			
1.4. Tick Route efficiency	2.14. Compare Route factor with threshold value (1.6) (*)		
	2.15. Route factor > 1.6		4.3. “This route is [route factor] times as long as the direct distance, indicating a less efficient connection for the studied O-D-pair. Is this a problem? Yes/No/Comments”.
	2.16. Route factor $\leq$ 1.6		4.4. “This route provides an efficient connection for the studied O-D-pair”.
1.5. Tick Route functionality	2.17. Detect use of local roads in route chain, other than at beginning and/or end of chain (*)		
	2.18. No undesired use of local roads?		4.5. No message
	2.19. Undesired use of local roads?	3.6. Highlight detected undesirable local road sections.	4.6 “Highlighted local road sections are undesirable in that stage of the route. Is this a problem? Yes/ No/ Comments”.
	2.20. Derive Time - Path diagrams for all routes (desired, fastest, shortest) (*)		4.7. Show Time - Path diagrams
	2.21. Select route of which time-path diagram has smallest angle of inclination	3.7. Highlight route with smallest angle of inclination.	
	2.22. Selected route is desired route....		4.8. “Desired route is most functional route”.
	2.23. Selected route is not one of desired routes		4.9. “The most functional route is not one of the routes you described as desired. Is this a problem? Yes/ No/ Comments”.

(*) See comments in text.

Table 2. *Actions which have to be taken to diagnose the road network safety. Actions should be taken by the user of STNP (1) and by the tool STNP itself, in the form of computing (2), and showing information on the map (3) and in the right-side column (4) on the screen.*

1. Action user	2. Action STNP	3. View on map	4. View in right-side column
1.6. Tick travel times	2.24. Is desired route...fastest route?		
	2.25. 2.24= Yes		4.10. “Desired route is the fastest route, indicating road users probably will use this route”.
	2.26. 2.24.= No	3.9. Highlight fastest route	
	2.27. If No, is difference larger than 10 min.? (*)		
	2.28. 2.27= No		4.11. “Desired route is not the fastest route. The difference in travel time however is small (...min.). Traffic diverting to the faster route is questionable”.
	2.29. 2.27= Yes		4.12. “Desired route is not the fastest route. The highlighted route is ....min. faster, indicating that road users will use this route instead of the desired route”. Is this a problem? Yes/ No / Comm.
1.7. Tick route safety	2.30. Is desired route...the safest route? (Use predicted accidents!!) (*)		
	2.31. 2.30.= Yes		4.13. “Desired route ... is also the safest route between studied O and D”.
	2.32. 2.30.= No		
	2.33. Calculate difference in predicted accidents between desired route and safest route.	3.10. Highlight safest route.	4.14. “Desired route ... is not the safest route. On the safest possible route (highlighted) ...less accidents per year are expected.” Is this a problem? Yes/ No/ Comm.
	2.34. Calculate difference between actual accidents and predicted accidents for desired route(s).		
	2.35. Actual accidents lower than predicted		4.15. No message

(*) See comments in text.

Table 2 continued.

1. Action user	2. Action STNP	3. View on map	4. View in right-side column
	2.36. Actual accidents higher than predicted	3.11. Highlight sections in desired route(s) where actual accidents is higher than predicted.	4.16. “The reported number of accidents on the route is higher than should normally be expected. On this route ....accidents are reported, whereas the predicted number of accidents is.... This could be an indication of deficiencies in the road form, or the presence of black spots. The sections with more reported than predicted accidents are highlighted”. Is there a problem? Y/N/C Report possible problems to engineering department.
1.8. Tick summary of results			4.15. Desired route.....: -Efficient/ Not efficient -Undesirable use local roads./ No..... -Most functional/ Not most functional -Fastest/ Not fastest -Safest/ Not safest
	2.37. Is 4.6, 4.9, 4.12, or 4.14 answered with yes?		
	2.38. No		4.16. End Route management
	2.39. Yes		4.17. “Do you want to change routeing of traffic?”
	2.40. If 4.17 is no		4.18. “Sure??”
	2.41. If 4.17 is yes, go to 1.9.		
1.9. Possible route man. techniques: -change driving speeds -add links -directional closures -closures			

Table 2 continued.

1. Action user	2. Action STNP	3. View on map	4. View in right-side column
1.10. Change driving speeds		3.12. Show desired route(s), and fastest route	4.19. Show time - path diagrams and changing table (*)
	2.42. Take user through changes (see explanation of 4.19.)		
	2.43. Recalculate (repeat step 1.3. through 1.8.)		4.20. “Do you still want to change anything? If yes, go back to 1.9 and choose another route management technique”.
1.11. Add link(s)			
1.12. Manually reassign traffic volumes	2.44. Go through 1.3. to 1.8. again		
			4.21. “Do you still want to change anything? If yes, go back to 1.9 and choose another route management technique”.
1.13. Directional closure(s)			
1.14. Manually reassign traffic volumes	2.45. Go through 1.3. to 1.8. again		
			4.22. “Do you still want to change anything? If yes, go back to 1.9 and choose another route management technique”.
1.15. Closure(s)			
1.16. Manually reassign traffic volumes	2.46. Go through 1.3. to 1.8. again		
			4.23. “Do you still want to change anything? If yes, go back to 1.9 and choose another route management technique”.
			4.24. If no, end route management.

(*) See comments text.

Table 2 continued.

Action 2.27:

Research indicates that motorists do not easily divert to other routes if differences in travel times are smaller than 10 minutes (Khatak, Schofer & Koppelman, 1991). If the difference in travel time between the fastest route and the desired route is smaller than 10 minutes, it can therefore not automatically be stated that all traffic will divert to the fastest route. The only conclusion that can be drawn is that the desired route is not the fastest route, but that the time difference is that small that it is not certain if, and how many, motorists will divert to the faster route.

Action 2.30:

For the calculation of the level of safety of desired routes ("is the desired route also the safest route") only the predicted accidents on links and intersections should be used. The use of actual accidents could include accident prone locations or black spots. Those deficiencies should be solved, but should not obscure the selection of the safest route.

Action 4.2:

Fact sheet for desired route(s), fastest route, and shortest route.

Distance Origin-Destination as the crow flies = ...km

	Desired route 1	**Desired route ...**	**Shortest route**	**Fastest route**
Colour in map				
Travel time				
Length, total				
rur. frway				
rur. expwy				
rur. madis				
rur. midis				
rur. local				
urb. frway				
urb. expwy				
urb. madis				
urb. midis				
urb. local				
Route factor (*)				
Acc. predicted				
Acc. actual				

(*) Route factor = travelled distance on route divided by the distance as the crow flies (previously referred to as "Crow flies factor" in project).

Action 4.19:

To change driving speeds and delays on routes, the user has to see both the routes on the maps and the time-path diagrams (see *Figure 1*).
A time-path diagram shows the use of different road categories as line sections with different angles of inclination. Delays at intersections are represented by vertical line sections. The diagram with the smallest overall angle of inclination (smallest angle of linear regression line) uses the highest share of high-category roads, and/ or has the smallest delays at intersections and is therefore the most functional route. The diagrams not only show immediately which route is the most functional route, but can also show deficiencies in routes (like large delays, frequently changing of road category, too many intersections etc.).

On the screen, the routes on the map and the time-path diagram have to correspond, so if the users clicks on a link or an intersection, the corresponding element in the diagram should blink.

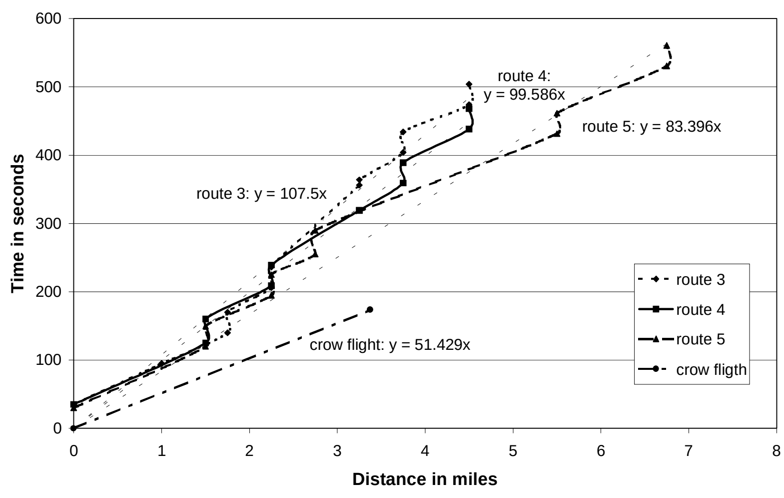


Figure 1. *Example of a time-path diagram.*

For each link or intersection on a route the user clicks, one of the following tables is presented below the time-path diagrams:

Selected section: Intersection #.....

	Type (signalised, priority, all-way stop, roundabout)	**Volume**	**Level of Service** (A-B, C-D, E-F)	**Delay**
Original				
Revised				

Selected section: Link #.....

	Road category	**Volume**	**Posted speed**	**Access density**
Original				
Revised				

The user can tick on the ‘revised’ cells and change the value. (If he changes Type or Road Category, the other values should change automatically). Every change in the table should directly give a recalculation of travel times, and show the results automatically in the time-path diagrams, so that the user immediately gets a feeling for how the time and path are changing. If the user changes values to impossible or unwise values (e.g. chosen intersection type cannot deal with the volumes, or volume-capacity ratio is otherwise higher than 0.85), the user should be warned.

If eventually the changes in the time-path diagrams confirm the user that he probably reached his target, the user should be able to click a ‘Recalculate’ button, after which the whole route management process from action 1.3. through 1.8 is repeated.

User information:

The difference in travel time for the used route and for the desired route gives an indication of measures to be taken.
The applicability of route management can be studied by comparing the actual (average) driving speeds for the studied routes. Actions:

a. Determine whether the actual driving speed on the undesired route can be increased (travel time can be increased).
b. Determine whether the actual driving speed on the desired route can be decreased (travel time can be decreased).
c. Change driving speed in the input of the model, and recalculate the travel times on the studied routes.
d. Determine if the change of driving speeds on the studied links is sufficient to redirect traffic (travel times on desired routes should be shorter than travel times on undesired routes).
   Research of Khattak, Schofer & Koppelman (1991) indicates that motorists do not easily divert to another route, if travel time savings are smaller than 10 minutes. If, however, friction and discomfort are increased (e.g. as the result of traffic calming measures) this threshold value could possibly be lower than 10 minutes.
e. If the adjustment of travel speeds is not sufficient to create a significant difference in travel times between desired and undesired routes, physical route management techniques can be applied (e.g. road closures, turning restrictions, one-way traffic), or new links have to be introduced in the network.

User information; Possible measures:

Measures in this section are discussed in more detail in section 4.5 ‘Route management techniques’.

- <u>Decrease travel times on desired routes.</u>
  Possible measures:
  - higher speed limits (and corresponding design)
  - reduction of delays at intersections:
  - reduction of the number of intersections
  - use of intersection types with smaller delays
  - traffic signal coordination
  - reduction of friction (and improving capacity)
  - reduction of number of accesses

- restriction/ reduction of turning movements
- reduction of number of crossings
- restriction/ reduction of roadside parking
- adding traffic lanes
- separating different road users
- increasing capacity of intersections
- providing bus bays at bus stops.

The measures described above also improve the reliability of travel times.

- <u>Increase travel times on undesired routes.</u>
  This option comes down to downgrading a road to a category with a lower speed limit. To support this lower speed limit, the design of the road has to be adjusted (see road form), and traffic calming measures have to be implemented. Possible traffic calming measures are:
  - narrowing cross section
  - vertical deflection
  - raised crosswalk
  - raised intersection
  - rumble strip
  - sidewalk extension
  - speed hump
  - textured crosswalk
  - horizontal deflection
  - chicane - one lane
  - chicane - two lanes
  - curb extension
  - curb radius reduction
  - on-street parking
  - raised median island
  - traffic circle.

  The tools described should not be used separately and in isolation. The effects of isolated implementation of speed reducing measures is very low. If the choice for increasing travel times on certain routes is made or considered, the designer has to chose to which design speed the speed should be lowered (for example from 50 km/h to 30 km/h). To lower the design speed, a number of the mentioned measures should be implemented.

- <u>Physical redirection of traffic.</u>
  Assuring undesired routes:
  a. have longer travel times than the desired routes, or even excluding undesired routes, or,
  b. cannot be used because of a:
  - directional closure
  - diverter
  - full closure
  - intersection channelization
  - raised median through intersection
  - right-in/ right-out island.

- Route guidance signs.
  The effectiveness of this route management technique is doubtful. Road users with knowledge of the local network will not take longer routes. This measure will only be effective for road users without knowledge of the network.

- Improved recognition of road types.
  The road form should clearly reflect the function of the road. In this way the choice of routes with a function too ow for the trip is prevented.

3.4. Policy formulation

- General policies:
  - Use of roads should be in accordance with the function of the roads (i.e. volumes on residential roads should be low, residential streets should only be used by traffic with either origin or destination in that particular street, flow traffic should make use of the highest available road category).
  - The fastest route between a specific origin-destination pair should also be the safest route.

- More specific policies:
  e.g. ‘Preferred level of service’ on arterials and collectors.

4. Library information

4.1. Understanding

Route management is the practice of:
- Persuading road users to use the routes as intended by the designer of the network.

The aim of route management is:
- To match the use of the roads and routes in a network with the function of those roads and routes.
- to provide the roads and routes with one of the three functions: through, distribution, and access. Mixed functions should not be created, because the increased friction and uncertainty on the desired behaviour cause a higher level of risk.

In general, the following techniques can be used for route management:
- Assure that travel times on the desired route are shorter than on other routes, by either:
  - decreasing travel times on the desired route, or/ and,
  - increasing travel times on other routes (e.g. by traffic calming, or signal timings)
- Preclude undesirable route choices, by movement restrictions (limiting accesses on flow and distributor roads, restricting turning movements on flow and distributor roads).
- Route guidance signs.
- Improved recognition of road categories.

4.2. Factors affecting motorists route choice

- International research (Vaziri & Lam, 1983; Jansen & Den Adel, 1986; Southern, 1988; Ueberschaer, 1971; Bamford & Read, 1990) indicates that route decisions are affected by the following factors:
  Key factors:
  - travel time
  - travel distance
  - estimated fluctuations or uncertainties in travel time (congestion, bottlenecks, number of give ways, number of roundabouts, number of zebra crossings).
  - reliability of travel times and travel distances.

  Additional factors:
  - stressful driving
  - direct and expedient route
  - safety.

- Vaziri & Lam (1983) indicate that the most important factors are travel time, reliability and stressful driving. The authors found that the scores of those three individual factors are almost equal, indicating that all three should be considered in traffic improvement strategies and traffic assignments.

The remaining factors are only included in the route choice, if the three most important factors do not result in one conclusive resulting route.

- Southern (1988) found that distance and time are indicators of route-choice for nearly 80% of trips. The remaining 20% was not explained by either time or distance.

- Ueberschaer (1971) found that 86.3% of all route choices were explained by travel time. If travel distance is used as criterion, this percentage of explained route choices dropped to 65.0%.

- Vaziri and Lam (1983) found that drivers did not always rank the route choice reasons with the same weight for trips to work, as for trips *from* work. This leaves some uncertainties in the relative importance of the route choice criteria.

- During the trip, motorists can adapt their chosen route to changing road and traffic conditions. Adaptations are mostly based on radio traffic information or variable message signing. Most motorists judge the radio traffic information as more reliable than other types of information. (Spyridakis et al., 1991).
  Bonsall, Whelan & Page (1995) describe the results of a stated preference experiment, in which up to 88% of all drivers changed to alternative routes when they received a radio message indicating a 10 minutes delay on the primary chosen route.

- Research by Bovy & Bradley (1985) showed that the route choice of bicyclists is more sensitive to fluctuations in road and traffic conditions. For cyclists travel time is also the most important route choice criterion, directly followed by surface type and the presence of separated bicycle facilities. Results show that improvements in surface (from rough to smooth) and facility (from none to separated path) can compensate for travel time losses of up to 30%.

4.3. Distorting factors

- Stated preference research in the Netherlands showed that motorists have a limited knowledge of the possible routes to their destination. 75% of the respondents know no more than 2 or 3 alternative routes (Jansen & den Adel, 1986).

- The choice of a route is based on the expectation of relevant route characteristics. Those expectations are often not correct. Bovy (1986) found that only 50% of the motorists who claim to take the shortest route actually indicate the shortest possible route.

- Research by Wenger et al. (1990) indicated that once commuters have chosen a route, they are very reluctant to change to alternative routes. Those commuters who changed their familiar route, reported higher levels of stress during their trip. Similarly the results showed that commuters rarely changed mode of transportation or time of departure on the basis of information received before the departure.

4.4. Threshold values for the influence of travel time

- Research of the en-route route changes in response to delay (Khattak, Schofer & Koppelman, 1991) showed that increasing delays on the preferred route cause more drivers to divert (see *Figure 2*).

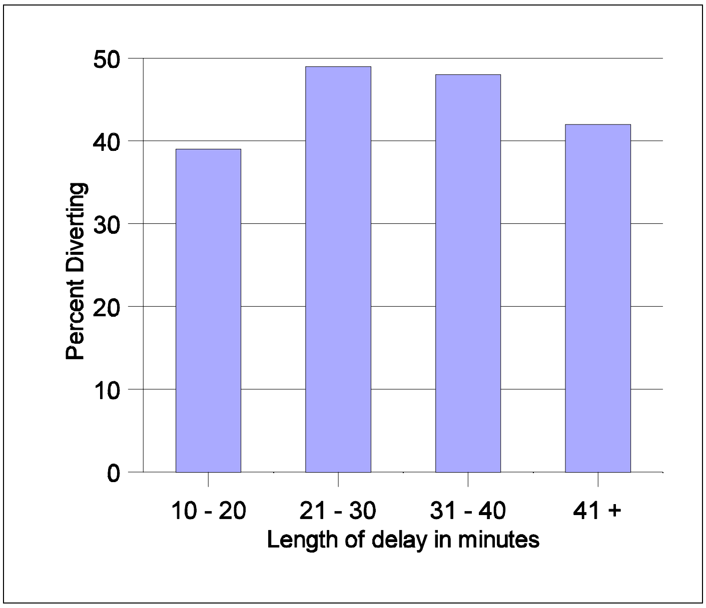


Figure 2. *Percentage drivers diverting in response to various lengths of delay (Khattak, Schofer & Koppelman., 1991).*

The decreasing percentage for delays longer than 41 minutes is explained by the authors with the fact that delay is perceived incrementally. Furthermore the number of observations for the larger delays was rather small.
Other variables such as weather conditions affect the decreasing number of diverted motorists at the upper end of the delay distribution. If delays are long because of bad weather conditions, no alternative route is likely to be more appealing.
The study indicated a reduced sensitivity to units of delay as trip time increases; a given percentage increase in the length of delay has the same effect on diversion, regardless of the current value of delay. For example, a 5 minute increase in a 10 minute delay, has the same effect on driver decisions as adding a 15 min to a 30 min delay.

In the study of Khattak, Schofer & Koppelman (1991), drivers needed a minimum travel time saving before diverting to another route. In the study this threshold value for travel time saving was 10 minutes.
This indicates that travel time on the desired route should at least be 10 minutes shorter than on the alternative route, to be able to divert motorists from the alternative to the desired route.
In the determination of this threshold value, only travel time increases due to delay were considered. If the amount of friction and discomfort on a route increases (e.g. as a result of traffic calming measures), this threshold value of 10 minutes could possibly be lower.

4.5. **Route management techniques**

As described in the previous sections, travel time and reliability of travel time are the most important criteria for route choice. Furthermore the knowledge of the network, and the expectation/ recognition of relevant route characteristics are important conditions in the route choice.

Route management tools are:
- Travel time reduction on preferred route
- Travel time increase on other (alternative) routes
- Improve reliability of travel times on preferred routes.
- Physical route guidance
- Route guidance signs
- Improve recognition of road types.

The aim of route management techniques is to match the use of the roads in a network with the function of the network.
In a properly designed network the fastest route and the safest route coincide, and there are no rat runs through residential areas. If in an existing network this is not the case, route management techniques can be used to redirect traffic from undesirable routes to desirable routes.

4.5.1. *Travel time reduction on preferred routes*

- Reduction of travel times on through-roads/ through-routes can be established by:
  A. higher speed limits (and corresponding design speeds)
  B. reduction of delays on intersections
  C. reduction of friction
  D. direct connection without detours.

A. <u>Higher speed limits (and corresponding design speeds)</u>

- See Road Form Library information.

B. <u>Reduction of delays at intersections</u>

- Reduction of number of intersections.
  Generally the delay at intersections is considerably higher than on road segments (lower passing speeds, lower capacities). A larger number of intersections therefore increases delays (see *Table 3*).

Signals per mile	Percent increase in travel times (compared with 2 signals per mile)
20	0
30	9
40	16
50	23
60	29
70	34
80	39

Table 3. *Percentage increases in travel times as signal density increases (Gluck, Levinson & Stover, 1999).*

- Use of intersections types with higher capacity, so that smaller delays occur (see *Table 4*).

Intersection type	Capacity in vehicles/ day
Uncontrolled (priority to the right)	1,000 - 1,500
2-way stop/ 2-way yield	5,000 - 12,000
4-way stop	12,000 - 18,000
Roundabout single lane	20,000 - 28,000
multilane	35,000 - ? (1)
Signalized	20,000 - 80,000 (2)

(1) Varies from country to country
(2) Depends on the number of lanes for the different movements

Table 4. *Maximum capacity of different intersection types (May, 1997).*

- Adding left-turn lanes (see *Figure 3*).
  Right-turn lanes are generally not recommended on non-signalized intersections, because they limit (or even block) visibility of straight going cars. The increase in capacity caused by right-turn lanes is marginal.

  The capacity of a shared lane is generally less than that of a through-lane, and under typical urban or suburban conditions might be about 40 to 60 percent of a through-lane. Thus, along a four-lane arterial, provision of left-turn lanes would increase the capacity from about 1.5 to 2.5 lanes in each direction - a 33 percent increase.

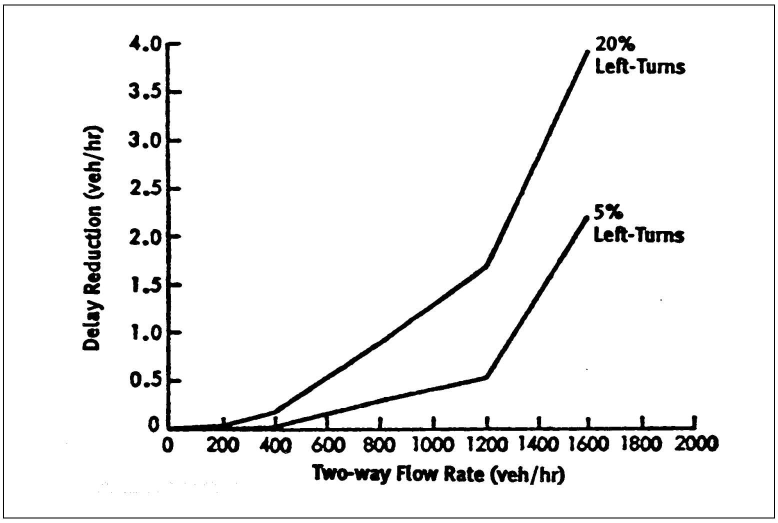


Figure 3. *Delay savings of left-turn lanes on two-lane rural highways (Gluck, Levinson & Stover, 1999).*

- Traffic signal coordination on signalized intersections
  The increase in capacity and reduction of delays is highly dependent on the type of coordination used.

C. Reduction of friction

- Reduction of number of accesses (see *Table 5*).

Access density (access/km)	Running speed adjustment factor
0	1.00
5	0.96
10	0.93
15	0.90
20	0.86
25	0.83
30	0.79

Table 5. *Speed adjustments for access density: British Columbia (Gluck, Levinson & Stover, 1999).*

- Restriction/ reduction of turning movements.
  A reduction or restriction of left-turn movements (at intersections or accesses) can reduce delays.
  For an opposing volume of 800 vehicles per hour, and a through-volume of 800 vehicles per hour, the percentages of through-traffic delayed and stopped were estimated as in *Table 6*.

Percent of left-turns	Percent delayed	Percent stopped
20	33	72
50	70	182
100	110	379
150	122	544
200	96	684

Table 6. *The percentages of through-traffic delayed and stopped at different percentages of left turns (800 vehicles per hour through, 800 vehicles per hour opposing; Gluck, Levinson & Stover, 1999).*

For an opposing volume of 200 vehicles per hour and a through-volume of 800 vehicles per hour, the percentages of through-vehicles affected were as in *Table 7*.

Percent of left-turns	Percent delayed	Percent stopped
20	6	11
50	18	28
100	27	67
150	38	95
200	52	122

Table 7. *The percentages of through-traffic delayed and stopped at different percentages of left turns (800 vehicles per hour through, 200 vehicles per hour opposing; Gluck, Levinson & Stover, 1999).*

- Reduction of the number of crossings
  Reduction of delays and increase of capacity highly dependent on type of crossing and volumes of crossing traffic.

- Reduction/ restriction of roadside parking (no quantitative effects available).

- Other measures to improve capacity on links:
  - adding lanes
  - separating different types of road users
  - providing bus bays at bus stops.

D. Direct connection without detours

- Travel times can be reduced by providing direct connections without detours.

4.5.2. *Travel time increase on alternative routes*

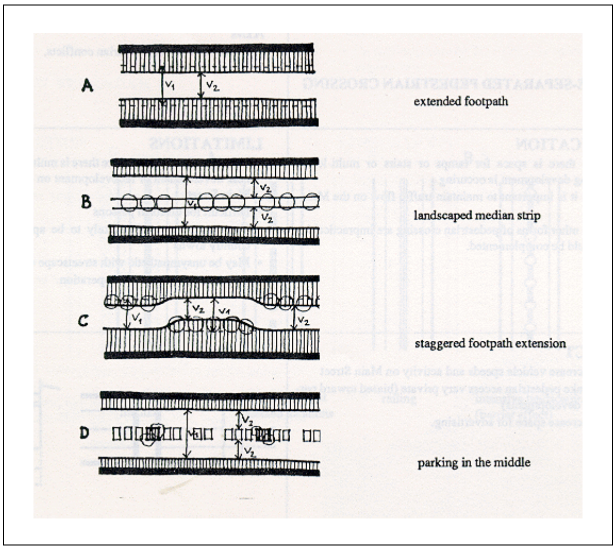
- Travel times on through-roads (flow and distributor) should be smaller than travel times on alternative routes, to prevent motorists taking short cuts. This can be established by lowering travel speeds on the alternative routes (traffic calming).

- Tools to increase travel times (TAC, 1998):

Measure	**Effect on speed reduction**
A. Narrowing cross-section	Substantial, especially with oncoming traffic
B. Vertical deflection	
- Raised crosswalk	Substantial
- Raised intersection	Substantial
- Sidewalk extension	Minor
- Speed hump	Substantial
C. Horizontal deflection	
- Chicane - one lane	Substantial
- Chicane - two lane	Minor
- Curb extension	Minor
- Curb radius reduction	Minor
- On-street parking	Minor
- Raised median island	Minor
- Traffic circle	Substantial
Assuring undesired routes have longer travel times than the desired route:	
D. Physical redirection of traffic	
- directional closure	Substantial
- diverter	Substantial
- full closure	Substantial
- intersection channelization	Substantial
- raised median through inters.	Substantial
- right-in/ right-out island	Substantial
E. Signing	
- Maximum speed	Minor
- Traffic-calmed neighbourhood	No effect

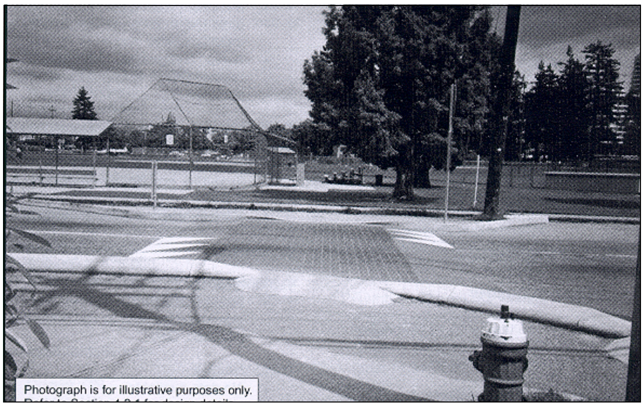
- The tools described should not be used separately and in isolation. The effects of isolated implementation of speed reducing measures is very low. If the choice for increasing travel times on certain routes is made or considered, the designer has to chose to which design speed the speed should be lowered (for example from 50 km/h to 30 km/h). To lower the design speed, a number of the mentioned measures should be implemented.

A. Narrowing cross-section



B. Vertical deflection

Raised crosswalk:



Raised intersection:

Sidewalk extension:

Speed hump:

C. Horizontal deflection

Chicane:

Photograph is for illustrative purposes only.

Curb extension:

Photograph is for illustrative purposes only.

Curb radius reduction:

Photograph is for illustrative purposes only.

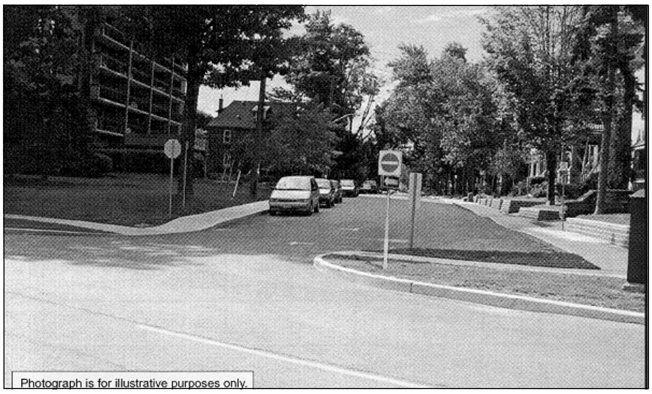
On-street parking:

Raised median island:

Traffic circle:

D. Physical redirection of traffic

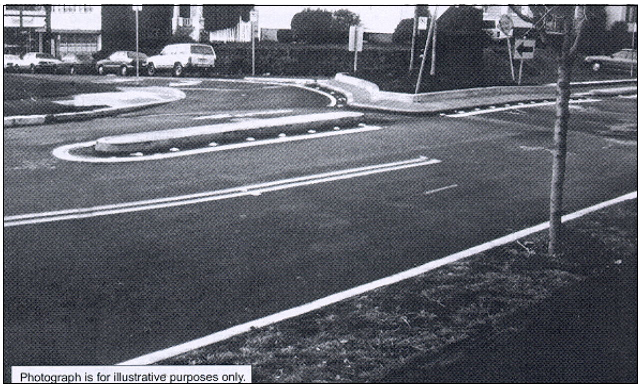
Directional closure:



Diverter:

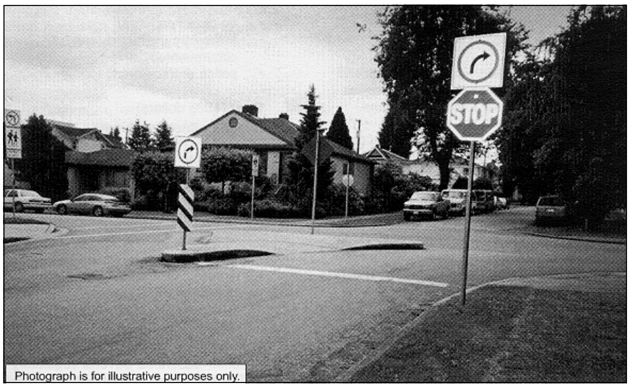
Full closure:

Intersection channelization:



Raised median through intersection:

Right-in / right-out island:



4.5.3. *Route guidance signs*

- Theeuwes & Godthelp (1992) estimate that 5-10% of all vehicle kilometres are caused by getting lost.

- The use of route signs can:
  - guide traffic on desired routes in the network
  - reduce the amount of travel caused by getting lost.

- Information display techniques (Alexander & Lunenfeld, 1990):

a. Spreading:	Spreading reduces the chance for overload at high processing demand locations by moving lower primacy information sources upstream or downstream, thereby reducing processing load.
b. Coding:	Coding increases drivers' information handling capacity and reduces their reaction time. Codes include colours, shapes, and numbers.
c. Repetition:	The short term memory span of most drivers is 30 seconds - 2 minutes. If a time greater than this short term memory span intervenes between the receipt of information and its action, drivers may forget the message. Repetition can also prevent information being missed because of sight blockings.
d. Redundancy:	Redundancy displays the same information on one or more information carriers, using two or more display techniques.

4.5.4. *In-vehicle guidance and information*

- Research in a simulated route-choice situation (Bonsall & Perry, 1991) proved that overall, about 70% of the advice was accepted. It was observed that the acceptance of route advice depended on the quality of the advice, the quality of previously received advice, the drivers' knowledge of the network and on the extent to which advice was corroborated by other evidence.

- In-vehicle guidance can have the same advantages as the use of route information signs, namely: reduction of searching traffic, and guidance to desired routes.

- If the in-vehicle guidance system is traffic actuated, traffic can be guided to take short cuts in case of blockings or congestion on main routes. This could lead to conflicts between the function of roads and the actual use of those roads.

4.5.5. *Improve recognition of road types*

- A clear and recognisable road classification is the most important and effective route management technique.

- The function of each road in the network should be clear by the design of the roads and the connecting intersections. Each road type and intersection type should have a uniform design.

- Road user expectancies have an important influence on their behaviour and performance in traffic. The navigational task can therefore be simplified if road and route characteristics correspond with road user expectancies.
  The use of the right (desired) road types is improved if the function of the roads is clearly recognisable by its design characteristics or indicated by route signing (Alexander & Lunenfeld, 1990; Theeuwes & Godthelp, 1992). To improve recognition, each road type and intersection type should have a uniform design, making its function clearly recognisable.

- To improve recognition and predictability, the number of road categories should be limited. Preferably no more than three functions and corresponding road categories should be distinguished:
  - through-function
  - distributor function
  - access function.

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Appendix 1 Calculation of travel times

To be able to calculate reliable travel times on routes in the network, the posted speed on the network links should be adjusted for delay and friction on the route.
Generally used is the technique described in the Highway Capacity Manual (TRB, 1985), in which a large number of adjustment factors for intersection delay, and friction (both caused by road geometry and traffic congestion) are used.
This Highway Capacity Manual technique to convert posted speed to an average running speed however requires detail input data, that is usually not available in the network planning phase (e.g. signal timings, detailed geometric information, and detailed information on traffic composition and turning movements). Moreover, gathering the required input for the entire network, would take an enormous amount of time and work.
Despite warnings in the Highway Capacity Manual (“If knowledge of signal timings and quality of progression is lacking, there can be no meaningful estimation of arterial Level of Service, even on a planning level”), a simplified technique is used to calculate travel times on routes.
In this technique, travel times on links will be adjusted for friction caused by the density of driveways on the links, and for the probability of congestion on links. Delays at intersections are dependant on the type of intersection, type of priority regulations, direction of movement on each intersection in the route and on the estimated level of service.

Travel time on links:

The first step is the adjustment of the posted speed for friction caused by the access density (density of driveways on links), according to the following table (Ministry of Transport and Highways, 1992):

Speed adjustments for access density

Access density (Access/ km)	Running speed adjustment percentage
0	100
5	96
10	93
15	90
20	86
25	83
30	79

Once the average running speed is determined, travel times on links can be adjusted for delays caused by congestion, by:

$Ta = To\ (1.5)^{V/C}$
Ta = adjusted travel time
To = travel time at zero flow (free flow speed)
V = volume on link
C = predicted capacity of link

Link capacities (vehicles per lane):

Freeway:	2000
Expressway:	1800
Major Distributor:	1200
Minor Distributor:	1200
Local:	1200

Delays at intersections:

Signalized intersections

Values based on Teply, S. & Evans, G.D. (1989).

Average delays (all directions) at signalized intersections:

Delay	Level of Service	Average delay per vehicle (sec.)
Small	A - B	10
Average	C - D	15
Large	E - F	25

Small delays: very low volumes or coordinated signals.

Priority intersections (both T-intersections and four legged intersections)

Values based on Brilon, W. & Grossmann, M. (1991).

Average delay at priority intersections:

Direction, Level of Service		Average delay per vehicle (sec.)
Priority vehicles		0
Non-priority vehicles,	Level of Service A - B	15
Non-priority vehicles,	Level of Service C - D	25
Non-priority vehicles,	Level of Service E - F	45

All-way stop-controlled intersections (four-way stop and three-way stop)

Values based on: Kyte, Zegeer & Lall (1991).

Average delay (all directions) at all-way stop intersections:

Level of Service	Average delay per vehicle (sec.)
A - B	10
C - D	20
E - F	30

Roundabouts

Values based on Höglund (1991).

Average delay (all directions) at roundabouts:

Level of Service	Average delay per vehicle (sec.)
A - B	5
C - D	7
E - F	10

Input requirements Safer-TNP

The large differences in delay between priority and non-priority vehicles at priority intersections, makes it necessary to indicate the priority direction at priority intersections in the input of link and node information in Safer-TNP. E.g. node δ is a priority intersection; the connecting links are a, b, c, and d; the priority direction is from link a to link c.
Planet-GIS then has to take into consideration which direction is travel on each intersection on the route (does the route follow the priority direction or not).

Links require the following input information:
- Link type (road category/ sub-category): Capacity can then have a default value or, if requested, a user-specified value.
- Posted speed (travel speed is calculated)
- Access density (number of driveways per km).
- Volume (average daily traffic and peak hour volume)
- Number of lanes (capacity per road type is specified as peak hour capacity per lane)
- *Link function (not directly needed for route man. and travel time)*
- *Land use (not directly needed for route man. and travel time)*

Intersections require the following input information:

Step 1: Intersection type	Step 2: Priority direction	Step 3: Level of Service
a. Signalized	Not relevant	A - B (e.g. coordinated or short cycle times)
		C - D
		E - F
b. Priority	from link.... to link....	A - B
		C - D
		E - F
c. All-way stop	Not relevant	A - B
		C - D
		E - F
d. Roundabout	Not relevant	A - B
		C - D
		E - F

T-intersections and four-legged intersections can automatically be identified by Planet-GIS. Other intersection information is already specified in link information

In the calculation of travel times and in the calculation of the fastest route, Planet GIS should also determine whether or not a certain route uses the priority direction on a priority intersection!!!

Interrupted flow

If V/C ratio's are higher than 0.85, the level of service is poor (Level of Service E or F). Flows are interrupted and travel speeds are reduced. In design this high levels should be avoided. In Safer-TNP, the V/C ratios in existing situations and in situations after reassignment should therefore be checked. If V/C ratio's are higher than 0.85, the user should be warned for the possibility of congestion or poor operations.
Because the exact capacity can only be calculated in a detailed study of the specific road section, Safer-TNP can not give the exact capacity for all network elements. The user should be advised to check the network element in more detail of the V/C ratio is higher than 0.85 ("The V/C ratio on link/ intersection...... is very high. Are you sure the capacity is sufficient to accommodate the traffic volumes?").

The following estimated values for the maximum capacity can be used (May, 1997; TRB, 1985).

Maximum capacity of different intersection types:

Intersection type	Capacity in vehicles/ day
Uncontrolled (priority to the right)	1,000 - 1,500
2-way stop/ 2-way yield	5,000 - 12,000
4-way stop	12,000 - 18,000
Roundabout single lane	20,000 - 28,000
multilane	35,000 - ? (1)
Signalized	20,000 - 80,000 (2)

(1) Varies from country to country
(2) Depends on the number of lanes for the different movements

The abovementioned values are indications. The exact capacity of intersections is highly dependant on the geometric design and the distribution of volumes on the intersecting roads.
The influence of the number of lanes on intersecting roads for yield- and stop-controlled intersections is small, because the capacity is mainly determined by gaps in the traffic stream on the major road.

Maximum link capacities (vehicles per lane, per hour):

Freeway:	2000
Expressway:	1800
Major Distributor:	1200
Minor Distributor:	1200
Local:	1200

To calculate the capacity in vehicles per hour, the abovementioned values (veh./day) can be divided by the peak hour factor (approximately 10). If the exact peak hour factor in a certain area is known, this value can be used. If the exact value is not known a default value of 10 can be used.

Appendix 2 Route factor

Blunden & Bunton (1962) appear to have been the first to introduce the term ‘Route factor’, which is defined by:
Route factor = (average distance via routing system) / (average direct distance)

Route factors for theoretical routing systems

Twelve theoretical routing systems:

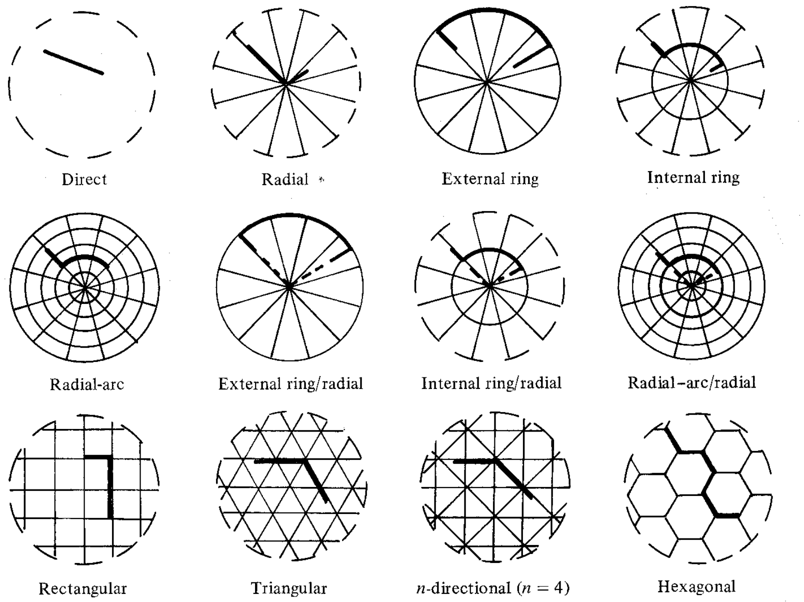

Figure 3.1. Holroyd’s twelve routeing systems (source: Holroyd, 1966).

Theoretical route factors in a unit circular city with uniform and independent distribution of origins and destinations (Vaughan, 1987).

Routing system	Route factor
Direct	1
Radial	1.473
External ring	2.472
Radial then Arc	1.313
Radial-arc	1.313
External ring / Radial	1.325
Radial-arc / radial	1.098
Rectangular	1.274
Triangular	1.103
Hexagonal	1.274
10 deg. Spiral ring	1.075
30 deg. Spiral ring	1.046
60 deg. Spiral ring	1.173
80 deg. Spiral ring	2.073

Route factors for real networks (Smeed, 1971):

City / Cities	Route factor
Central area London	1.27
Average for central area of Washington DC and six UK cities	1.27
Average for entire area of Washington DC and six UK cities	1.27
Average for central area of six Australian cities	1.32
Average for entire area of six Australian cities	1.32

Preferred value of routing system or route:

From the examination of route factors, Vaughan (1987) concludes that a routing system or a specific route will have a chance of being realistic if it has a route factor of about 1.3.
This factor however is based on the average value of several randomly chosen origin-destination pairs. It can therefore be used as a preferred value for the network as a whole, but not for a preferred value for one specific origin-destination relation.

Although it is difficult to judge when a single route can be called ineffective, the following table gives some indication.

Route factors for different trips

Routing system	Internal trips	Cross-cordon trips	Through-trips
Direct	1	1	1
Radial	1.47	1.47	1.57
Internal ring			
Rg= 0.50	1.42	1.36	1.4
Rg= 0.25	1.38	1.39	1.49
Rg= 0.00	1.47	1.47	1.57
Radial - arc	1.22	1.22	1.23
Radial - arc/ radial	1.1	1.1	1.07
Rectangular	1.27	1.27	1.27

If a calculated route factor for one specific route is larger than 1.57 (approx. 0.6), one could say that the detour is larger than what can be expected on average.
Proposed is to use the route factor value of 1.57 (approx. 0.6) as the value above which the user of Safer-TNP should be warned that the selected route could be ineffective. Whether this value is workable should be determined in pilot studies.