A sustainably safe traffic and transport system: déja-vu in urban planning?

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Contribution to the conference 'Traffic safety on two continents', Lisbon, Portugal, September 22-24, 1997

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1. Introduction

The question of how to reconcile urban development with traffic structure, traffic flows and transport modes is by no means a new one. The trends in thinking on the subject, varying from 'traffic free' through 'reduced traffic' to 'everything out of the way for the car', still fail to converge towards any ideal or optimal situation. Various concepts have been propounded and perhaps even adopted for a period. They then disappear only to reappear - sometimes years later, possibly in modified form.
One example would be the urban underground railway. Thirty years ago this was considered unacceptable in The Netherlands because of the large-scale demolition of residential property; now it would seem that the idea is once again viable.

Whether there is any sort of collective learning process for the trends described here would seem very doubtful. The mistakes of the past are repeated at every new emergence - consider the current planning trend to give residential streets the original 'old-fashioned' look, with long straight roads and cars parked on both sides. That this particular design leads to diminished road safety has been proven by many studies conducted in the days before the introduction of the Dutch 'woonerf' en the 30km/h zones.
A number of common points link the various designs and structures.
First, they are mostly confined in their concept to fulfilling one or two purposes or aims, (such as the 'accessibility' of the inner city or the 'liveability', i.e. amenity of an area).
Second, they come into existence only with the greatest of difficulty (given the resistance of those they affect).
Third, they disappear, sometimes after but a short time. An example would be the residential area scheme (Janssen & Kraay, 1984) which was attempted in the Dutch borough of Rijswijk, (with the help of millions of guilders of government subsidies), and which disappeared only fifteen years later when the area was returned to its previous layout.

At the town and city level, urban development and traffic planning involves using the town as a permanent 'laboratory', in which theoretical considerations concerning the optimum traffic structure are given little chance, or serve merely as a background, in order that a common thread through practice and policy be maintained. There are towns which, in executing their traffic policy (or at least a part of it), manage to maintain that common thread for years. (OECD, 1990; Janssen, 1991). However, the thread is thin and its strength seems to depend entirely upon the individuals charged with the execution of the policy. Of course, it is the urban local authority whose responsibility it is to give form and substance to the traffic policy but whether the 'powers that be' will ever emerge from the laboratory stage remains to be seen.
National government attempts to influence traffic policy at local level by subsidising projects and by promoting the exchange of knowledge and expertise. This influence has either a very rigid form, (as in the Rijswijk case, where the residents had the residential area scheme foist upon them), or a much too loose form, as in the case of a subsidised plan for a new residential estate between Utrecht and Vleuten-De Meern, which was

replaced by the local authority with a plan which, from the point of view of traffic aims, was exactly the opposite (Van Wilgen, 1995).

An urban traffic system unites many functions and must score on many points in order to fulfil the overall set requirements. A system which scores well on one point will probably score badly on another. For example, a tunnel for cyclists may well score well on road safety but will score rather badly on social safety (Van der Voordt *et al.*, 1978).

The traffic system of an urban area remains a framework of compromises and sub-standard solutions. If one aspect is placed to the fore and an attempt is made to have this aspect reflected in all the different functions, the character of the whole framework is adversely affected. The 'trick' is to find the right combination of aspects and functions for each situation. This mix is not necessarily the most logical or rational solution, nor is it the ideal solution as derived from theory, but is the solution that will meet with the least resistance.

In this article I draw a distinction between concepts which are devised and executed across complete urban areas (the so-called 'pan-urban' projects) and those within individual residential areas. Urban development projects are usually confined to the latter, residential area, level. Modifications to the traffic structure are more often than not of a pan-urban nature, because traffic is not confined to one small area of a city, but tends to diverge across the whole road network.

There follows a sketch of developments and trends based on a somewhat personal selection from influential books and reports dating from the early post-war years (or in some cases even earlier). This review of the 'old masters' is designed to examine whether:

- the knowledge and insight attained in days gone by is being applied;
- the urban traffic system can ever be controlled in all its facets;
- pan-urban concepts have a chance of success anyway.

This sketch does not pretend to be complete. It does however give a good picture of the most important developments. We will then go on to examine how these concepts relate to the most modern of the pan-urban concepts: the 'sustainably safe' traffic and transport system. A question to be raised here is whether this concept in fact introduces anything new. Using a fully worked-through example, we will show the possible application of 'old' knowledge to this latest concept.

2. Pan-urban concepts

2.1. The city of the future

In 1924 Le Corbusier published his book *Urbanisme*, later translated into English and frequently reprinted as *The city of tomorrow* (Le Corbusier, 1987). In this book, Le Corbusier introduces the concept of a city with a traffic system on many - mostly underground - levels. The centre of his city consists of four large office buildings clustered around the Central Station.

This Central Station has six levels:

first floor:	taxis
mezzanine:	cars
ground floor:	pedestrians
first underground level:	metro
second underground level:	local and regional railway
third underground level:	long distance railway

With this structure, Le Corbusier aimed to reduce the number of streets in the city centre by two thirds. He applied a grid system to the street network, whereby the distance between the gridlines would be 400 yards (approximately 360 metres). A metro station is sited in the centre of each square of the grid.
Le Corbusier arrived at this plan because he was concerned that the explosive growth in vehicular traffic in Paris (in 1924) could never be contained by the existing, or even a potentially expanded, street network. He commented: "To save itself, every great city must rebuild its centre." Another quote reads: "A city made for speed is made for success." That he was rather inclined toward grandiloquence is underlined by a further quotation: "Great cities are the spiritual workshops in which the work of the world is done."
Of course, this adventurous concept has never been put into practice, but this does not detract from the fact that Le Corbusier recognised at an early stage that the urban traffic system is not able to accommodate excessive traffic volumes and that major modifications are necessary, possibly to also involve controlling the number of vehicles.

2.2. Buchanan

The Buchanan Commission's report *Traffic in Towns* (Ministry of Transport, 1963) has achieved fame far beyond the shores of the United Kingdom. The report describes all aspects of urban traffic problems and has a pan-urban approach. The report is so well known that we need not dwell too deeply on it here.
Buchanan *et al*. conclude that the increase in vehicular traffic is not to be halted and the road network will therefore have to be drastically modified. Rather than opting for a plan making extensive use of public transport *à la* Le Corbusier, they plump for large scale clearances to make way for new trunk roads. This vision has plagued many cities for years.
Buchanan *et al.* also include so-called *environmental areas* in their plan, to take on the functions of the lower-traffic residential area.

These environmental areas may not be too large lest the number of vehicles exceeds the *environmental capacity*. This is defined in the simplest of terms, the main criterion being the ease with which a street in the area can be crossed. This 'crossability factor' is however variable according to the number of vulnerable pedestrians (old people, children: the *level of vulnerability*) and the degree to which a street can be 'read', i.e. the degree to which the situation in the street can be seen at a glance: (parked cars, number of obscured exits, driveways etc.: *the level of protection*). This approach means that, for example, a street with an average *level of protection*, and a nine-metre wide carriageway may carry only one hundred vehicles per hour (see *Figure 1*). The variation in *environmental capacity* means that the actual size of an *environmental area* is heavily dependent on its physical location.

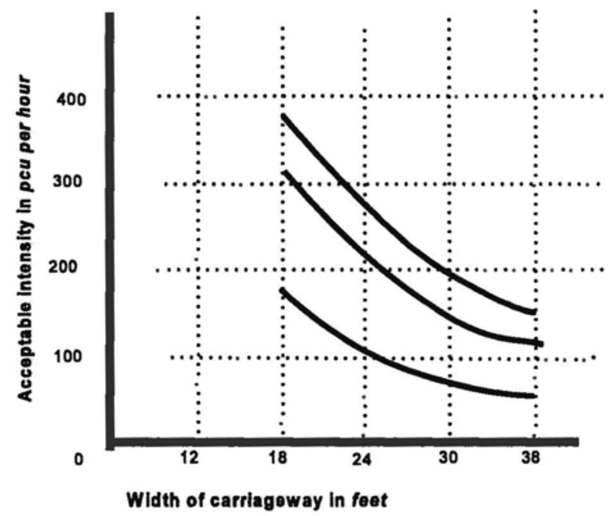

Figure 1. *Permitted number of vehicles per hour at an average level of protection. Source: Ministry of Transport, 1962.*

2.3. Traffic and the city

A classic Dutch study is *Verkeer en Stad*, (*'Traffic and the city'*, Goudappel & Perlot, 1965). This slim volume contains an illustration which is probably the most copied in all the road traffic safety literature. It shows the arrangement of roads and streets according to traffic volume and residential functions.
Under the heading 'urban traffic planning' the authors deal with such aspects as road classification, (from urban motorway to footpath. This classification is still used or cited by many, thanks to that one illustration. However, the origin of the classification is unclear. In no edition of Goudappel, early or late, is its derivation or basis given.
According to the authors, the design criteria for roads and streets are as follows (Goudappel & Perlot, 1965 p. 101):

I All areas of the urban region must be equally accessible.

II The weight and numbers of vehicles must be spread as evenly as possible; heavy concentrations of traffic must be avoided.

III The roads should follow the pattern of origins and destinations (straight connections between origin and destination) as closely as possible whereby traffic movement through areas which do not form part of a given route is avoided.

IV By ensuring that roads and junctions are of appropriate dimensions, a fluent and constant traffic flow should be made possible. Road classification is an important aid to this.

V In considering future situations, special attention should be paid to achieving less traffic within an area, with the emphasis on time, rather than on distance.

From three possible traffic systems - radial, tangential (grid) and 'other', Goudappel & Perlot opt for the tangential system, with special regard for criterion II, above. For inner cities, they prefer the ring or loop. The authors further lay down requirements for the positioning of housing, which must be easily accessible on the one hand and must be on a street which is primarily residential in nature on the other. Commenting on concepts after the Radburn model (see § 3.1), they write:
"The question is whether further separation in residential areas, where the residential function is already more important than the traffic function, would not lead to a sterile solution. Many would prefer to live in a residential (through) street rather than in a closed-off, dead-end cul-de-sac, *with little activity.*[1] *It is not out of the question that concentrating a limited number of families in the modern equivalent of the courtyard village will lead to social conflict."*

2.4. Organic structure?

In the well-known *A city is not a tree,* Alexander (1966) denounces the organic structure (also known as the hierarchical or 'tree' structure) advocated and applied at the time. He asserts that the organic structure is not suitable when it comes to facilitating the many possible connective relationships between urban elements. The organic structure is capable (at most) of connecting consecutive elements, while the grid structure enables various criss-cross connections to be made. Moreover, the 'tree' structure is often coupled with a separation of urban functions (e.g. housing far from the employment zones) which, according to Alexander, impairs the urban dynamic. He believes that the organic structure is so frequently considered because it is a simple concept and because people have difficulty in understanding the patterns and connective relationships involved in more complex structures.

2.5. Forming an image

One book that is essential to any review of the literature on urban development is *The image of the city* by Lynch (1960). This book also has strong roots in the field of traffic planning. It reports on a study into the

[1] It is probably unnecessary to note that many people now live very happily in such 'dead-end' streets.

perception of the city and of the image that those who live or work there form of it. That picture is determined by five elements: routes, boundaries, areas, junctions and landmarks. Using these five elements, one's image of the city can be put into words.
A field study was held in three American cities: Boston, Jersey City and Los Angeles. Lynch *et al.* interviewed sixty people in each city and asked about their personal perception of the physical aspects of these cities. In Boston, the interviewees were also asked to view photographs of the relevant area and follow a given route. Passers-by were also asked questions.
Lynch has provided the designers of urban infrastructure with an extra assignment: to consider whether the elements of their plans will be sufficiently recognisable for future users to be able to orient themselves. An oft-heard complaint about areas with an organic structure is that it is very difficult to find one's way around. In such cases, the designer may well have failed to provide a good mixture of Lynch's five elements.

2.6. Conclusions

The pan-urban concepts outlined here are the results of an idealistic mixture of town planning premises and aims, together with traffic planning premises and aims. No better concepts have been developed since the time of Buchanan and Goudappel. As was proposed in the introduction, continuity in the areas of urban planning and traffic structure planning is often missing. It is difficult to pinpoint cities where such concepts have been fully carried through. If we confine our examination to the infrastructure of urban arterial roads, then we see that many cities have applied Buchanan and Goudappel's concepts (Janssen, 1991), although of course there are countless local variations. In many overseas countries, a uniformity of approach in pan-urban road network structure has been adopted (Dijkstra, 1991).
The best known example is the Swedish SCAFT directives (SCAFT, 1968), which tackled the concept of 'sustainable safety' long before the issue had gained popular currency. In fact, a somewhat less extreme version has since been adopted (TRÅD, 1982). In The Netherlands, it has not yet proved possible to find a uniform approach. Pan-urban concepts are able to succeed at the level of pan-urban structure, but the carrying through of plans at lower levels (district, neighbourhood, street) is abandoned or is subject to so many modifications that the original concept is no longer recognisable.

3. Structures at district and neighbourhood level

3.1. The organic traffic system

In *Die autogerechte Stadt,* Reichow (1959) presents his ideas about a traffic system which shows certain similarities to the construction of organic structures such as a leaf. From a central arterial road, numerous side-shoots and sub-branches diverge, like the veins on the leaf.. This concept was first put into practice in the (for its time) pioneering residential area Radburn (United States). Later 'organic structure' gave way to the rather more prosaic term, 'hierarchically structured' road network.
Reichow separated the street networks of cars, cyclists and pedestrians, and introduced a new type of road junction which precludes most of the unsafe encounters between the various types of road user. Reichow was able to apply a similar model in a German residential area. The system is not necessarily pan-urban and can be applied in any residential area. The disadvantages of the organic traffic system are that routes are often unclear and indirect, and that a sole main road has to deal with all the incoming and outgoing traffic of the area. This means that criss-cross connective relationships throughout the area (think for example of delivery services) are almost impossible. Some Dutch residential areas of the 1970s would seem to be based on an adaptation of Reichow's model.

3.2. Man & Motor

Ritter (1969) describes the many incompatibilities between man and motor. He gives many examples of areas, mainly residential, where the car is given reduced status. Many of these examples are to be found in Sweden and the 'new towns' of the United Kingdom. He touches but briefly on the pan-urban traffic question, although it should be said that his book does present a good impression of the era in which it was written.

3.3. Limited access

An important article was written by Marks (1957). In it he reports on an accident study carried out in Los Angeles. Two traffic structures were examined: a grid system and a system with 'limited access' (see *Figure 2*). The grid system showed almost eight times as many accidents as the limited access system. At four-arm junctions, the number of accidents per year per junction was three times higher than in the limited access system.
According to Marks (1957) a safe design is characterised by:

- a limited access system, preferably with access roads approximately 350 metres apart (a distance that was also mentioned by Le Corbusier);
- no streets linking two main roads;
- (local) distributor roads to be included only if they do not cross through-streets and only when they join arterial roads on one side only;
- junctions with four arms are to be avoided wherever possible in favour of simple T-junctions.

These recommendations were 'rediscovered' years later and formed part of the major Dutch *Demonstratieproject herindeling en herinrichting van* *stedelijke gebieden [Demonstration project in the redesign of urban areas]* (Janssen & Kraay, 1984)

3.4. Conclusion

The structures at district and neighbourhood level appeal somewhat less to the imagination than do the pan-urban concepts. Nevertheless, they have been applied in a number of locations. In the 1970s and later, notions such as '*autoluw*', '*Verkehrsberuhingen*' and '*traffic calming*' became common property (see Pfundt, 1979; OECD, 1979; TRRL, 1988 amongst many others). The design requirements listed by Marks (1957, see above) should have been taken on board earlier. Each country made its own analyses before reaching more or less the same conclusions and requirements.

4. A modern-day concept

4.1. Introduction

Following the outline of the old concepts, there now follows a short analysis of the modern concept of the 'sustainably safe' traffic and transport system. The concept has far-reaching ambitions. The Dutch national government has set a goal of 50% fewer road traffic fatalities and 40% fewer casualties by the year 2010, (taking the figures for 1985 as the baseline). Because these aims go further than merely following an existing trend, a sustainably safe traffic system with structurally low accident figures has to be found. An important component of such a system is a sustainably safe design for the Dutch road network in which roads are divided into a limited number of categories. Each category has a clear and unequivocal function for traffic and must be easily distinguishable from the other categories.

Road safety must become an integral element of the entire Dutch road network (both urban and rural). It is inevitable that this will have major consequences for urban planning and traffic systems planning.

The national working party 'Categorisation of Roads' laid down several requirements for the categorisation of roads against the background of 'sustainable safety' (C.R.O.W, 1997). These requirements are of two types: functional and operational. The functional requirements can be regarded as the basic criteria for dividing the roads of the network into the various categories. For each of the roads thus given a specific category, there are also operational requirements which concern the most important characteristics of the cross-section, the longitudinal profile, the classes of traffic allowed to use the road and their position on the cross-section. These requirements should be included in the existing guidelines for urban and rural roads.
The requirements for the road network, as formulated by the working party are as follows:

- largest possible residential areas;
- a maximal part of the journey using relatively safe roads and routes;
- journeys as short as possible;
- the quickest and shortest routes to coincide;
- avoid the necessity to search for directions/destination;
- easily recognizable road categories;
- limit and make uniform the number of possible types of design;
- avoid encountering oncoming traffic;
- avoid encountering traffic crossing the road being used;
- separate types of traffic;
- reduce speed at potential points of conflict;
- avoid the placement of obstacles on the carriageway.

These requirements apply to the entire road network and have not yet been itemised according to their possible application to the urban road network. They are in part applicable at pan-urban level (where referring to routes and journeys) and in part at lower levels. Vis & Krabbendam (1994) modified the theory of the requirements to apply at the pan-urban level (to the city of

Nijmegen). It comes as no surprise that Vis & Krabbendam consider major modifications to the road network to be necessary.

In contrast to the pan-urban concepts discussed, the 'sustainably safe' concept relies on detail. This is unavoidable, given that the road safety elements have to be influenced at the level on which the road users themselves are to be found. However, we have seen that the pan-urban approach is strongest in its general points and not in the details. For the 'sustainably safe' concept to succeed it will be necessary to make the pan-urban road network uniform and thus, finally, leave the 'laboratory phase'.

4.2. Relationship to aspects other than road safety

This is the point on which the 'sustainably safe' approach is lambasted from all quarters. To what extent can a concept with safety as its main aim meet the requirements of the various sorts of users of the urban infrastructure?[2] At this point we should stop to consider what value we actually attach to 'safety'. Safety is an integral part of Buchanan and Goudappel's concepts, even though it may not be stressed as such. Meeting the various other requirements does not necessarily mean that any degree of safety has to be sacrificed, but the ideological aspect of 'sustainably safe' may well be lost if the other requirements are given full rein in the negotiations at local level. When considering the physical size of the low-traffic residential areas, it is probably true to say that the *environmental capacity,* as defined by Buchanan, is a better criterion than the current demand that vehicles may spend only a few minutes in such an area.

4.3. What is new about 'sustainably safe'

A modern concept need not be totally new. Many a good tune is played on an old fiddle and the heavy emphasis on safety which is part and parcel of the 'sustainably safe' approach is also characteristic of existing Swedish policy (SCAFT 1968). In Sweden, the concept was partially successful but was later somewhat diluted (TRÅD, 1982).
What *is* new in the 'sustainably safe' concept is the combination of elements which then affects all levels (from pan-urban to street) and which also takes account of the road users themselves (although still too heavily weighted towards car drivers). Here, it would seem possible to incorporate various of Lynch's ideas on traffic engineering, since 'sustainably safe' requires various elements to be present at street level in order to provide points of reference for the road users (Dijkstra, 1997).

4.4. Conclusion

We must ask ourselves where the Ritters, Reichows, Corbusiers, Lynches and Goudappels of today are to be found. Not because we need to call up 'the heavy mob', but to establish that there is precious little trend-setting vision to be detected at the moment and that there are few authoritative people or institutes able to lead the way in urban traffic development. The works of these 'old masters' are, in a sense, timeless and can not be

[2] A consideration here is that the road system was originally designed with (only) motorized traffic in mind (Van Minnen 1992).

read too often. They provide much which can be adapted and applied.
But nobody wants to find answers on the bookshelf - every generation wants to reinvent the wheel, a lot of pleasure lies in doing just that.
However, while the number of different types of wheel may increase, there is no more movement in that which they're attached to.
Or has the ebb and flow of progress reached an end and are we now seeing a state of equilibrium?

5. Sustainably safe residential areas

The first requirement of a 'sustainably safe' system is that the residential areas should be as large as possible. At the same time, the volume and complexity of traffic in these areas must be as light as possible. Finding the correct size for a residential area is a very old design problem. If the area is too large, too much traffic is generated on the area's roads; if it is too small, it provides too little value to the residents. Next to the size of the area, the structure of the road network also determines the amount of traffic, especially on the roads enclosing the area. In turn, the road network structure at urban level determines whether traffic finds its way into an area which is neither its starting point nor destination (through traffic).
Many have tried to find the 'ideal' traffic structure for residential areas. That structure is heavily dependent on the priorities one wishes to establish. It goes without saying that in the 'sustainably safe' approach, the safety aspect comes to the fore. However, one cannot simply ignore the aspects of accessibility and 'liveability' (i.e. the avoidance of nuisance from noise and fumes). Further, initial investment and maintenance costs should be considered and should satisfy certain criteria.
In this section we shall examine the extent to which the various forms of traffic structure contribute to road safety, accessibility and 'liveability'. Further, the role of investment and maintenance costs (insofar as details are available) will be examined.

5.1. Three kinds of structure

The history of traffic planning has provided us with three road structures for residential areas: grid (Alexander, 1966), limited access (Marks, 1957) and organic (Reichow, 1959) (see *Figure 2*). Experience has taught us that road safety in residential areas is best served by a system which is based on the limitation of access and speed (organic structure or limited access), and that the 'liveability' and accessibility are better served by a grid system. We will return to consider the cost of the respective systems later.

5.2. Indicators

We shall further examine the above mentioned aims concerning road safety, accessibility and liveability and will work through the theory of putting these aims into action using several indicators having a direct relation to the network structure. The degree of road safety is directly related to the total number of vehicle-kilometres driven, the route's 'design speed' (e g. that 85% of the vehicles using the route do not exceed a certain speed), and the density of junctions. We can express the accessibility here in terms of length of journey within the residential area and on the surrounding roads (which is of importance if the journey requires significant non-direct travel on these roads).
Speed itself is also important. However, within the residential areas speed is not a variable because it will in theory be more or less the same on all streets, namely a maximum of thirty kilometres per hour. The 'liveability' factor will be assessed according to the traffic volume (on any one stretch of road) and the total number of vehicle-kilometres driven.

The cost of the road structure depends primarily on the number of kilometres of road laid, the cross- section and the number of additional provisions, most notably those intended to reduce speed. There are of course more indicators - and more advanced indicators - which we could use for our purposes. However, for this review, those chosen are perfectly adequate.

5.2.1. *Road Safety*

In some residential area traffic structures, vehicular traffic makes part of an internal journey (i.e. from one point in the area to another) via the surrounding road network. For the purposes of calculating the total number of vehicle-kilometres driven this movement has to be included. Van Minnen (1993) calculated the total vehicle-kilometres for various schematic road structures. He made corrections for lower speeds in residential areas and thus he was actually calculating the journey *time* of the movement, (vehicle-kilometres driven per time unit). A grid structure with many connections to the surrounding road network has the shortest journey time. A simple organic structure has a journey time of almost 30% more than that of a grid. The difference in journey time between a limited access structure and an organic structure is negligible.

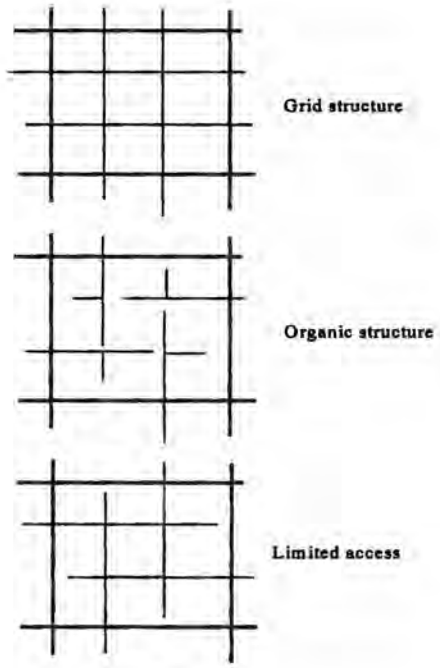

Figure 2. *Schematic representation of three types of road structures.*

In general, the number of junctions is directly proportional to the total road distance in a traffic network (Jansen & Bovy, 1975). However, in more unusual structures, such as the limited access and organic, this rule is not so strictly applicable. In these structures, the number of junctions is deliberately limited (see *Figure 2*). The organic structure has fewest junctions, followed by the limited access structure. In general, simple three-way T-junctions are beneficial to road safety (Janssen & Kraay, 1984). Such junctions are common in limited access and organic structures and this is a point in favour of these structures.

5.2.2. *Accessibility*

Accessibility, as expressed in terms of the journey distance, is heavily dependent on the extent to which indirect travel is necessary. The organic structure in particular requires much indirect travel on surrounding roads. Holroyd (1966) calculated the journey distance for a circular area, using various structures. He takes as his norm a direct 'as-the-crow-flies' journey from one point to another in the same area. A journey via a grid structure is 1.3 times longer and a journey via a circular route (as necessitated by the organic structure) is 2.5 times longer than the direct route. Accessibility would thus seem to be well served by the grid structure.

5.2.3. *Liveability*

The diffusion of traffic across the network is directly related to the density of the network and the number of junctions (exchange points). For the purposes of comparing the three different structures, we will assume that traffic density is more or less constant. We have already established that an organic structure has less junctions than a limited access structure and that the grid structure has the most. The grid structure therefore offers the most opportunities for an even diffusion of traffic across the network.
The average densities per road section are lowest in this form of structure. In an organic structure, each junction has a constant flow of traffic joining the road which gives access to the surrounding roads. In the example shown in *Figure 2*, the traffic volume on the surrounding roads in the organic structure and the limited access structure are much the same, but other examples can be given in which the organic structure demonstrates unfavourable concentrations of traffic.

5.2.4. *Cost*

The total length of a traffic network's roads will be greater in a grid structure than in either of the other structures. However, the differences are small, especially when taking into account the difference in speed control measures necessary. In a grid with long straight stretches of road, and therefore higher speeds, more such speed-limiting measures have to be introduced. The cost of the grid structure is therefore made unfavourable.
The road cross-section depends on the anticipated intensity of traffic. There are many urban connections which are very wide in comparison to the amount of traffic using them. Against this are enough examples of narrow profile roads which are used jointly by much motorised and slow traffic. It would seem that the cross section of the road is not dependent on structure type.

5.2.5. *Final conclusions*

The above findings are summarised in *Table 1*. The limited access structure scores well on all points. The positive aspect of this structure is that existing grid structures can be modified into limited access structures. It is much more difficult to transform a grid structure into an organic structure.

5.3. **Further research required**

Over the course of many decades, several authors have turned their attention to the subject of traffic structure. They seem not to have made regular reference to each other's work and conclusions. It would be enlightening to undertake a complete study into effects of various forms of traffic structure on road safety, accessibility, liveability and cost. That research must involve:

- the theoretical and mathematical links between the various network variables;
- the simulation of traffic movements in the various networks (preferably also taking into account the presence of various types of road user);
- the empirical assessment of the results of the foregoing sections of the study.

From such a study, we will be able to provide a firmer basis to the arguments in favour of a rigorous redesigning and rebuilding of the road networks.

	Grid	Limited access	Organic
Road Safety	-	+	++
Accessibility	++	+	-
Liveability	++	+	-
Cost	-	++	+
Relative scores have been awarded to each aspect. The score '-' indicates that an aspect has scored badly: high costs, many accidents, a lower 'liveability factor', poor accessibility.			

Table 1. *Scores of three structure types on aspects of road safety, accessibility, liveability and cost.*

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