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Road architecture hardware and traffic qualities in urban areas. Some Polish research and experiences

1. General identification of the problem

Each traffic system includes the following two interdependent components that form the traffic architecture or road architecture:

a) the traffic environment in its constructional and functional form, i.e. traffic hardware or static road architecture like roadways, sidewalks, buildings or trees (in brief: road architecture in the strict sense), and
b) man as the traffic subject (e.g. the pedestrian, cyclist, driver or passenger) i.e. traffic software or kinetic road traffic architecture (in brief: man in traffic).

There are two reasons at least that provoke reflection upon the relations between transportation infrastructure and traffic qualities in Polish urban areas:

a) according to actual percentage relationships of motor traffic intensity, accidents, population and network length, the probability of injury or death in urban traffic related to traffic on highways is about I9 to I, and
b) more than 70 per cent of all pedestrian casualties occur in cities.

A road is both a socio-spatial and a technical composition. Hence, road architecture should form and organize road space in real shapes necessary to meet the material and psychic needs of man. It must take into account the following considerations:

a) communication and transportation needs,
b) traffic qualities, but first of all safety,
c) functional requirements,
d) compositional aspects,
e) protection of the human and psychic environment,
f) topographic conditions,
g) geological properties,
h) engineering restraints,
i) material and texture treatments of pavement, and
j) road maintenance problems, services, operations, etc.

These considerations form an ergonomic complex, which has long been known, but which now in the age of motorization is very often neglected and forgotten. We know the three architectural rules: „dispositio" = technical construction, „decor" = art and aesthetic, and „distributio" = economic use of constructional means, as formulated about 2000 years ago by the Roman architect Vitruvius. In 1812, the Polish humanist Sierakowski said:

„Roads must be short, comfortable, safe and beautiful".

2. On traffic qualities

Fundamentally, the qualities desired in traffic are expressed in terms of safety, time, economy, comfort and convenience. These basic qualities are interdependent and inextricably woven into the fabric of traffic. The problems relating to basic traffic qualities were faced and stated many years ago. Today, in the age of expansion of motorization we see new aspects of old problems as the old problems combine in new forms. Our perception is sharpened by sharing pertinent discoveries in cause-effect and in choice-consequence relations. However, we continually want better traffic operations with greater benefits: greater safety, less trip time, less over-all cost, higher comfort and greater convenience.

It must be added that all of these qualities at their maximum levels are unattainable at the same time. If we get what we demand in one quality, we will get less in another because of the many limitations or restraints in a traffic/transportation system. Each basic quality has its desirability compromised by restrictions. Interacting as they do, each quality must complete with the others for position in the composite standard. One should remark that a road traffic/transportation system is open to all kinds of road users that walk, cycle, drive or take a bus, tram or urban underground. It must be open, of course at equal levels of service to both able-bodied and handicapped people. But we must not forget that contemporary man has become more and more „homo motoricus" and in contact with such pedestrians as children, invalids and the elderly, he often does not take into account their disabilities.

It is very difficult and in fact illogical to rank traffic qualities in priorities. It is also very illogical to compare the basic qualities of each without evaluation of measures, which in the scale of value above all respect the human element in choice-consequence relations. For example, accident cost as a result of detailed road safety is quite different from the travel cost as a result of bus fare. In some cases, in investment projects it is acceptable to first compare the definite basic qualities, but only in calculations of techno-economic effectiviness.

The relationships between traffic qualities and between traffic safety and road architecture are clear, though very often understimated and sometimes even neglected. Basic traffic quality and remaining qualities as well are ingluenced by road architecture. The most important philosophy is that all types of traffic should be able to use the existing roads, however without discrimination against any type of traffic, and that road architecture must be created and managed on the whole as a contact sphere between man and the urban environment, but not as a conflict one.

3. On traffic safety in general

Up to the present, in Polish statistics and research man as driver, cyclist or pedestrian has been defined as the main causer of accidents. However, studies have shown that traffic qualities and, first of all traffic safety are defined not only by human behaviours and reactions in traffic, but in large measure by architectural barriers in each contact between man and road. Accident statistics, based on records filled out at the locations of accidents, indicate that the percentage of casualties caused by road conditions is quite low, about 0.4 to 0.7 per cent, varying over different periods. However, the qualification of these conditions is simplified and deficient.

Comparative analysis of some hundred traffic conflicts proves beyond dispute that the road, defined as the complex of infrastructural elements, and traffic regulations cause up to 15.0 per cent of all casualties. In the city of Poznań, more than 50.0 per cent of tramway derailments are due to infrastructure defects. But it must be noted that different documentations note various percentages of casualties caused by road defects: juridical criminal records 14.5 per cent, and insurance registers 21.0 per cent of analysed conflict situations.

Apart from the fact that pedestrians and certain categories of other users sometimes find the road hazardous to use, it is worth noting that 32.3 per cent of pedestrian casualties occur on pedestrian crossings, at intersections, at mass transport stops, and even on sidewalks. These places represent 52.5 per cent of all traffic accidents. Each accident results in an average of 0.13 killed and 1.17 injured person. A man injured in traffic and made 90.0 per cent incapable of work, costs the society 31 times his average annual salary. The accident rate, i.e. the number of accidents per 10,000 people, has fortunately declined in recent years and is now 9.7. Ten years ago it was 11.5, but in 1965 only 5.6. However, in some urbanized and industrial regions and agglomerations, the actual accident rate is 15.0 or more. The number of accidents per million vehicle-kms is now 0.62 (1975: 1.08), primarily due to fuel limitations.

It seems appropriate to supplement this data with some measures, including the average annual increases in per cent during the period 1975 to 1985, of the following relations:

a) population (birth rate: 0.96): motorization (private cars: 31.45) 32.76; motorization (private cars and motorcycles: 7.94) 8.27; accidents (:0.86) 0.90; killed in traffic (:3.24) 3.38; injured in traffic (:0.82) 0.85; number of dwellings (:1.84) 1.92; and
b) compared to the number of dwellings: motorization (private cars) 16.64; motorization (private cars and motorcycles) 4.32.

4. Definition of road architecture and identification of the urban traffic environment

The architecture of any object has its attributes which affect the psychic condition of man, hence evoking feelings and moods and thereby influencing his behaviour and action. This means that architecture (here meaning road architecture) acts both in a receptive and a productive manner. The improvement of road architecture means a reduction in traffic collisions. In addition, it may make possible an expansion of safer use of the road by those user categories which up till now have had difficulty in overcoming different, primarily technical barriers.

The Charta of Athen prepared in 1933 gives the main theses, which, among others, define the traffic problems in an urban area and demand the solution of these on an ergonomic basis, i.e. on a human scale rather than a vehicular one. The significant theses concerning urban traffic and environment are:

Thesis 76: To all structures and interactions in a city, the human scale should be used.

Thesis 77: Urban planning must be grounded on the following four functions of the human environment: home; work; recreation; and transportation.

Thesis 80: The new rapid means of transportation have destroyed the uniform rhythm of city life; they are a source of permanent danger; they congest the roads by traffic bottlenecks and ruin health.

It should be noted that these theses formulated more than 50 years ago, hold good even today. Nowadays the road architecture is more and more influenced by car traffic needs. In some cases, organic traffic, i.e. the pedestrians and cyclists, are ignored by drivers as well as being neglected by urban planners. Thus, it seems correct to cite on this theme what the Polish humanist Sierakowski said more 175 years ago:

„Roadadministrators are wrong in understanding the term „community" and they forget what the destination of the pavement is. Coaches and wagons do not form the community; only the pedestrians do so. Coach drivers are just the smallest part of the community. Thus, comfort and safety must be due first of all to this real community".

5. The composition of road architecture as related to ergonomic traffic

All people assume some accident risk by entering the traffic, since designing an accessible road does not guarantee the total safety of any person. The success of a road depends in great measure on the quality of the designer and his authentic knowledge about hardware and software road architecture. But the designer, city planner or traffic engineer in particular must be aware of users' needs, first of all those of pedestrians.

It can be observed that in today's traffic systems everybody walks for some distance, sometimes, perhaps making a complete journey. Accordingly, it can be seen that the category „pedestrian" refers to every traveller. But it must be said that the road has been created mainly by the physically able for their own population group. In Poland, about 15.0 per cent of the population, i.e. a round 5 million people, have a permanent handicap in motion, sight or hearing. In fact, the handicapped are all elderly in some measure and in contact with the road environment as are also children below the age of 15. Thus, all these traffic participants are mobility-impaired at some time and have difficulty negotiating roads.

A significant socio-technical research and design problem is how a road architecture must be created so that it may be acceptable for all traffic subjects, including the disabled. The disabled are more exposed to the risk of accident than the average able-bodied person, especially in poorly designed and often badly maintained roads. Continous maintenance is necessary to keep operations at a peak of efficiency. However, it must be stated that the road designer many times confines his conception to motor traffic alone. The same applies to traffic managers. In this context it seems right to point out that in Poland the driver is in 62.4 per cent of cases the cause of an accident. The same approximate percentage (i.e. 63.6) is found in accident statistics based on accident reports recorded at the site of such events in the Poznań urban area. In other documentation looking deeper at accident events, the percentage is much higher: in insurance registers 90.0, and in juridical criminal records even 97.0.

The rapid increase in the number of private cars has made sidewalks more and more blocked by the cars parked thereon. It sometimes occurs without administrative permission, since there are not enough public parking places and garages. Thus, the pedestrian is forced to move on narrowed footpaths much damaged by cars. Instead of a regular surface, we find poorly fitting concrete sidewalk or stone sections on which comfortable and safe pedestrian movement is doubtful. The same goes for many pedestrian crossings, those close to tram tracks being particularly deformed. On sidewalks and pedestrian crossings one finds many covers of sewage and communication wells or gutter gratings, which form physical barriers several centimeters high or deep.

Tree branches often obstruct the visibility of traffic signs and lights. Sometimes, especially near intersections and pedestrian crossings, these are certain to contribute to accidents. The road is full of traffic instruction and information.

However, the dimensions and locations of these and some advertising signs as well, efficiently obstruct the perception and comprehesion of fundamental traffic instructions, both for pedestrians and for drivers. Besides some traffic signs are located very low on posts, which make their perception and comprehesion doubtful and is indeed dangerous for pedestrians, especially for the blind. All these non-ergonomic situations are, according to new technical regulations, to be corrected.

6. A model approach to the quality of traffic systems

All five basic qualities may be expressed in reduced form by aggregating three of them, namely time, comfort and convenience, into a compound basic quality, namely „efficiency" of a traffic/transportation system. Thus, the complex „traffic/transportation quality" may be presented in the form of a three-parameter model, described by the following parametric fundamental functions, including some partitive ones:

Safety:

F_{saf} = (M + Veh,Ped),(R) + $Traf_{mvs}$, BO, Inf, Pl, TA, (Env), I

where the pertitive functions that explain the parametric contents in the parentheses are:

$f_{M,Ped}$ = PIEV, Q, Ph, Dis, ADI
f_R = RC, TSep, Amay, Apsy, Mai
f_{Env} = Met, DT, RL, APN

Economy:

F_{eco} = (TQ_{Veh}, TQ_{Ped}), Inf, C, L

where the partitive function in the parenthesis describing alternative traffic subjects, i.e. man in vehicle (driver) or as pedestrian is:

f_{TQ} = (M + Veh,Ped), $Traf_{mvs}$, R, Env = constant;

the function f_{TQ} includes the other partitive functions for R and Env; the same goes for (M + Veh,Ped),

Efficiency:

F_{eff} = R, RCap, MP_{Veh}/MP_{Ped}, $Traf_{mvs}$, BO, Inf, Pl, TA, Env;

this function also covers some already mentioned partitive functions. The partitive function f_{TQ} = constant is an ergonomic one. This equation means that if f_{TQ} equals a constant, i.e. a constant value, the energy consuption for motion is at a minimum.

The following notation is used in the presented parametric formulas:

M — Man as driver or cyclist,
Veh — Vehicle,
Ped — Pedestrian,
R — Road,
$Traf_{mvs}$ — Road traffic, concerning chiefly traffic mixture (structure), volume and speed,
BO — Behaviour in traffic of other road users (transportation means),

Inf – information system (traffic signs, traffic safety facilities, etc.),
Pl – Place of traffic (e.g. other traffic tempo in a big city for a driver coming from a small one),
TA – Traffic area (a known or unknown one); the parameters Inf, Pl and TA together form an „identification system",
Env – Environment conditions in the road space,
I – Incidental situations,
PIEV – Perception: intelligence, emotion and volition (will) as the complex of road user's attributes,
Q – Traffic qualification of the road user,
Ph – Physical condition of the road user (traffic participant), e.g. able-bodied, handicapped, etc.,
Dis – Measure of traffic discipline,
ADI – Image of accident danger,
RC – Technical road construction,
TSep – Traffic separation (e.g. one roadway for both directions, motorway, cycle path, etc.),
Amat – Material architecture of the road,
Apsy – Psychic architecture of the road,
Mai – Maintenance condition of the road,
Met – Meteorological conditions in the road space (e.g. rain, wind, etc.),
DT – Daytime (clear, dark, etc.),
RL – Road lighting (e.g. sufficient, perfect, etc.),
APN – Air pollution, noise in road space,
TQ_{Veh} – Traffic quality of transportation means,
TQ_{Ped} – Traffic quality of pedestrian motion,
C – Traffic (travel) cost,
L – Travel distance,
RCap – Road capacity,
MP_{Veh} – Application of motoric vehicle power (e.g. 50 km/h driving, road race, etc.),
MP_{Ped} – Application of motoric pedestrian power (e.g. walking, fast motion, etc.).

One should note that all the above named parametric functions describe the so-called „traffic avtivity model", i.e. the active behaviour of road users. They do not include passive road users, i.e. the passengers in private cars and public transportation means as well, because that category of traffic participants does not create the road traffic climate and only indirectly have an influence on traffic safety, economy and efficiency.

Fig.1 illustrates the interactions of the three above named fundamental traffic qualities and their situations in a traffic system which consists of four specified (or partitive) systems, considering the human, technical, ecological and informative content of traffic.

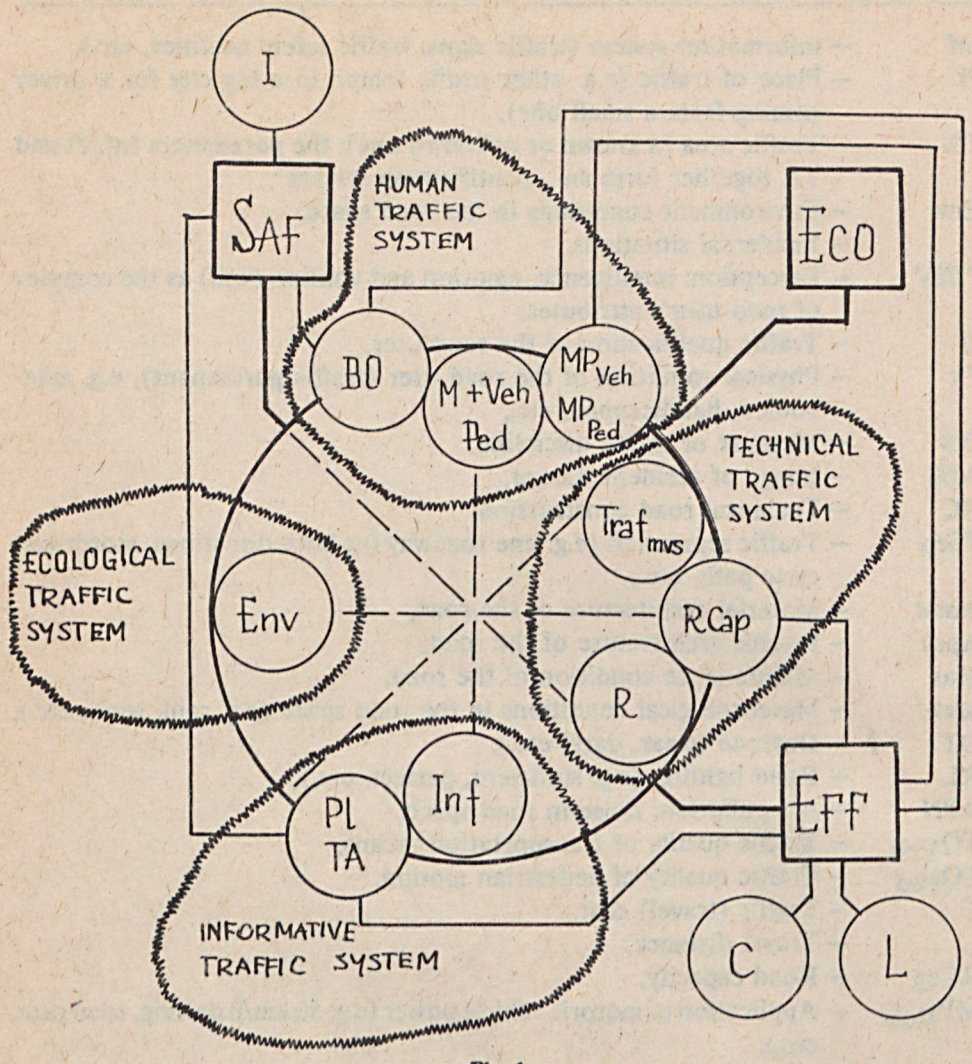


Fig. 1.

7. A catalogue of road architecture qualities

All public goods as, for example transportation infrastructure and services in road traffic have no quality at all. They only have characteristics. The demand has a special affinity to the supply, which depends on the aptness corresponding to its use. The demand gives a value to the good or the service which shows the ability of the good or the service to fulfill an affinity. This value is its quality.

Normally the quality has two components. First, the objective component, which includes the physical measurability of the characteristics. The other, i.e. the subjective one, shows the subjective evaluation of those characteristics measured in physical units. The components of quality can be used of course to describe the quality of a traffic/transportation system.

In the modern theory of traffic/transportation there are a great number of approaches to determining the quality of traffic/transportation systems. The intention of the approach presented here is to indicate the relevant characteristics (qualities) of traffic and, first, safety, given the cost of human life.

The qualities of hardware road architecture RA and the main content of the software, i.e. traffic safety TS, may be expressed by a catalogue of factors (specified partitive qualities, characteristics of both an objective and subjective nature), acting in single, in parallel or interdependently. Generally, there are six complexes of factors to consider, namely: the environmental, the techno-architectural, the informative, the traffic, the ergonomic and the road use complex. In particular, the proposed quality factors are as follows:

1. Topography (slopes etc.), RA+TS,
2. Vegetation (sorts, intensity and age of trees; grass, etc.), RA+TS,
3. Microclimate (volume and intensity of rain; snow; wind directions, etc.), RA+TS,
4. Road space structure (space types and elements, such as intersections; construction and location of buildings; number of building stocks; traffic lanes for various road users or for special transportation needs, e.g. transit, etc.), RA+TS,
5. Road area (colour; structure; material and division according to its use as roadway, sidewalk, etc.), RA+TS,
6. Image of road space (picture of the road), TS,
7. Road walls (sort, material, division and plasticity of facades), RA,
8. Road inner design (monuments; kiosks; advertising or other signs), RA+TS,
9. Monotony of the road (succession of spaces; succession of heights; extension and shape of house fronts), RA+TS,
10. Urban or regional continuity (building styles), RA,
11. Road use (use of road area; use of buildings, etc.), RA+TS,
12. Disturbance elements (narrow roads; small radii; earthworks, etc.), TS,
13. Repetitive elements and incidental processes (rhythm of trees; similar building styles; noise; dust; air pollution), TS,
14. Road lighting (sort, type, colour and establishment of lights; intensity and quality of lighting), RA+TS,
15. Maintenance problems (standard of roads and buildings; conservation effectiveness), RA+TS,
16. Identification (special structural elements, etc.), TS,
17. Orientation and clear structural management (logic of traffic routes; a competent system of order for road space structures; special orientation of buildings into perspective lines; visibility, etc.), TS,
18. Road information (road and street names; numbers of the buildings, etc.), TS,
19. Negative environmental features (dust; noise; vibration; smell; dirtiness; etc.), TS+RA,
20. Traffic convenience (accessibility of transport systems; traffic congestion and difficulty), RA+TS,

21. Safety and comfort of road infrastructure (safe and comfortable motion), RA+TS,
22. Social structure of the road (residents; travellers; and other road users), RA,
23. Traffic structure (mixture) (vehicles, here private cars; trucks; other mechanical vehicles, such as tramways; cycles, etc.), TS,
24. Traffic types (transit; local traffic, etc.), TS,
25. Traffic volume (peak hour traffic; average traffic, etc.), TS,
26. Traffic speed (normative, that is the maximum allowed, restricted, etc.), TS,
27. Traffic organization (traffic information; assignment of traffic safety facilities, etc.), TS,
28. Pedestrian activity (crossing roads; attractiveness of shoping, etc.), TS,
29. Activity of cycle traffic, RA+TS,
30. Road users' behaviour (behaviour of the man; operation efficiency of the vehicle, etc.), TS.

8. Classification of road architecture

The above named catalogue of observed hardware and software road architecture attributes could be summarized in the proposed model classification of that architecture. The classification is to be seen as a guide to ergonomic treatment, design and evaluation of road architecture. It is open, of course, and in principle can be explicated and detailed. The proposed classification considers two complexes of attributes, which are:

a) the material architecture complex with static (hardware) and kinetic (software) architecture elements, and
b) the psychic architecture complex including both material as well as immaterial architectural impressions.

The material road architecture includes the following:

a) the static, divided into many detailed architectures, such as:
   - —constant architecture, like building, roadway, tree, etc. or seasonal, like snow, flag, building materials, etc.;
   - —technical architecture, like building, sidewalk, road signs, etc. or organic, like tree, grass, etc.;
   - —transportation/traffic architecture, like roadway, road signs, etc. or non-transportation, like building, tree, etc.; and
   - —vertical architecture, like building, pillar, etc. or horizontal, like roadway, sidewalk, grass, etc.
b) the kinetic, divided into such particular elements as:
   - —traffic/transportation architecture, like pedestrian, cycle, car, bus, tramway, etc. or non-traffic, like illumination, electric clock, etc.;
   - —architecture of technical traffic means, like car, bus, tramway, etc. or organic, like pedestrian, horse, etc.; and
   - —architecture one meets constantly, like tramway, bus, etc. or only seasonally, like cycle, sledge, etc.

The psychic architecture of road space includes the following:

a) the material impressions of architecture, divided into the following special details:
   —architecture of shape; and
   —architecture of colour, but only partly,
   both with the features mentioned above;
b) the immaterial impressions of architecture, divided into the following special details:
   —architecture of light;
   —architecture of colour;
   —architecture of sound; and
   —architecture of smell,
   all with various characteristics named previously.

Knowing the general features of material and psychic road architecture allows the organization of the following:

a) traffic procedures of a quality generally acceptable for all road users, and
b) road architecture, i.e. the technical construction of the road and its equipment, aesthetic and communication function, based on minimizing uncomfortable traffic conditions and danger of accident.

9. Pedestrians and the handicapped in urban traffic

Among today's pedestrians we find many disabled persons. The disabled are more exposed to accident risk than the average able-bodied, especially in poorly designed and often badly maintained roads, as mentioned above. Though contemporary man is becoming more and more „homo motoricus", we do not forget that in today's traffic system everybody must, as before, walk for some distance, at least from a parking space to a work place or other destination. This means that the category „pedestrian" is applicable to every traveller.

It is evident that we assume some risk by entering the traffic, because even a famously designed and constructed road does not guarantee total safety. Continuous maintenance is necessary to keep operations at a peak of efficiency. To neglect maintenance work which should be done, will often cost more in delays, inconvenience, increased operating costs, and, possibly, serious accidents than the cost of proper early care. If the road is made accessible and safer, more disabled will use it with greater frequency. Good road composition thus produces fewer pedestrian casualties, reducing the number of invalids in society.

We should try to minimize today's inconvenient and unsafe traffic considerations regarding pedestrians, and especially the handicapped by successive elimination of all road elements and traffic procedures which create more difficulties or accidents. We must first protect pedestrians, since in contact with a vehicle, even a cycle, they suffer more damage than the drivers or passengers.

In order to improve traffic quality and above all to reduce the number of pedestrian casualties, the design and construction of pedestrian walk system,

including pedestrian crossings, must be based on the characteristics of a „critical design pedestrian", rather than on characteristics of a „normal design pedestrian". A critical design pedestrian may be typified by the characteristics of a disabled person, who on account of physical and/or psychic difficulty cannot contact with the road as easily as the average normal design pedestrian because of environmental constraints. The motion needs of the critical design pedestrian include those of the normal design pedestrian.

As already mentioned, the handicapped of all ages are in some measure in contact with the road environment as are children below the age of 15. Besides invalids, there are also two categories of traffic participants who are mobility--impaired at some time and having difficulty negotiating roads, and especially roadways. Special attention should be paid to children, since the examination of accident reports indicates the not unexpected finding that the young pedestrian is „at fault" in almost all young pedestrian accidents.

The accident descriptions lead to several accident stereotypes, including densely populated residential areas, reduced parental supervision, parked cars, and solitary young pedestrians running. The driver and/or the child will often not see the other untill the avaible reaction time is extremely small. Some general descriptions may help to characterize the young pedestrian accident as an effect of incorrect traffic behaviour, but in large measure it is also an effect of non-anthropometric and non--ergonomic road architecture hardware too.

It should be pointed out that:

a) children's diminutive stature limits their perception and makes it difficult for them to size up a traffic situation;
b) children are incapable of distributing their attention (they concentrate on one thing at a time — often play — or receive a vague overall impression);
c) they have difficulty discriminating the direction of sound; and
d) many believe the safest way to cross a road is to run.

The children are physically handicapped in utilizing traffic system/road architecture that is designed for the vehicle operator and the normal adult pedestrian. Studies of pedestrian anthropometrics indicate that parked car definitely block the driver's view of young pedestrians eight years old and under, which leads to a danger of accident when the pedestrians stand in the road next to a parked (often on the sidewalk) car and wait for a gap in traffic in order to cross. Such a situation also serves to block the young pedestrians view of oncoming traffic. Both forms of visual blockage tend to shorten pedestrian and driver reaction time.

The most effective form of pedestrian protection is residential road closure or movement of the two populations, i.e. drivers and pedestrians, on separate levels or traffic systems. Another form is quieting traffic in a similar form as the Dutch „Woonerf", especially in old city districts with narrow streets; in fact, one-way traffic and vehicle speed under 30 km/h are suitable in new large residential settlements as well. The next step to safer traffic is to clear the road, and especially the sidewalk, of parked cars. In the city center of Poznań parked cars block 74.0 per cent of all foot traffic areas.

10. Conclusions

In this paper it is argued that we know much more about accident effects and technical road construction than we know about the mechanisms underlying road user behaviour and the factors that contribute to behaviour that raises accident risk. Relatively little is known about road influence on accident danger. The studies made in Polish cities and in regional road networks state that the road causes many more traffic conflicts that are indicated in statistics based mainly on accident reports. In the statistics we do not find any information about conflicts without injuries. Thus, we have only a narrow picture of the real situation on the road.

Studies have also shown that the behaviour of man on the road is influenced by material and psychic road architecture, i.e. by construction, composition, arrangement and use of road space. Therefore it is of great value to know all significant road architecture attributes in order to consider them in the ergonomic design of roads.

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