SIMPAS: A MODEL OF THE FLOW OF TRAFFIC AT PEDESTRIAN CROSSINGS

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Abstract

In Hungary and in France, just like to the rest of European countries, one third of the casualties of accidents on the roads is constituted by pedestrians. Analysing traffic accidents and getting know better the behaviour of the participants in public transportation by scrutiny can help create safer conditions on the roads.

This article is aimed at presenting the basic features and characteristics of SIMPAS: a simulational model of public transportation worked out by INRETS (France) in close cooperation with the Faculty of Transportation Engineering at the Technical University of Budapest.

The simulational model and computer simulation programme has been developed to facilitate the study of the behaviour of pedestrians and drivers in traffic. The underlying conception behind the model is that individual situations in public transportation are determined from moment to moment by the impacts made by the participants of traffic upon each other. They constantly communicate with one another, and make their decisions independently on the basis of their own inner qualities, as well as pieces of information stemming from the environment.

This model-based computer simulation programme provides the analyst with a comprehensive set of data about the momentary state of the traffic and its participants. The programme makes it possible to carry out comparative analyses concerning the flow of traffic at pedestrian crossings equipped with different techniques of traffic control.

Keywords: pedestrian, simulation, pedestrian crossing, behaviour, traffic.

1. Introduction

In Hungary, similarly to other European countries, the number of casualties arising from traffic accidents is diminishing from year to year, although their number is still significant. In Europe, one third of people injured in traffic accidents are among pedestrians, and road accidents are fatal to the pedestrians in 12-30% of the cases, depending on which country one examines. To take the example of France, in 1994, there were 2230 pedestrians who were injured in a traffic accident, out of whom the number of those killed was 1126 (49 people out of 1000 injured ones) [1].

One can arrive at numerous deductions while analysing these and similar statistical data. Analyses of road accidents show that, on the average, pedestrians are to blame for accidents on the roads involving pedestrians in 63 per cent of the cases. Furthermore, upon the examination of pedestrians grouped according to their age, it is manifest that the proportion of guiltless pedestrians increases with age (*Table 1*). The majority of accidents caused by pedestrians are characterised by people carelessly and suddenly stepping onto the road surface, or people crossing roads behind a parked or stationary vehicle or by the red traffic light, or at forbidden places (*Fig. 1*). Based upon our own experience, we have observed that one tenth of pedestrians leave the pavement without first looking around, in which cases avoiding the collision is entirely up to the drivers and their possibilities.

Among collisions with pedestrians through the fault of motorists on the first place is the failure to give priority (*Fig. 2*). It is unfortunately becoming less and less fashionable among motorists to be courteous towards pedestrians; the only exceptions are children and parents with a pram. It is a general feature that motorists approach pedestrian crossings – considering it from the point of view of potentially giving priority – at an excessive speed, thereby limiting the chances of fulfilling their obligations of giving priority and stopping.

Table 1. Proportions of pedestrian accidents according to age groups

Pedestrian age group		Population	Average number of accidents between 1991 and 1995	Proportion of culpability	Weighted proportion of culpability
Younger than 6 years old	culprit		41.4	79.3%	0.4%
	participant	861850	10.8	20.7%	0.2%
	total		52.5	100.0%	0.3%
7–14 years	culprit		186.2	76.3%	2.2%
	participant	1201838	57.8	23.7%	1.2%
	total		244.0	100.0%	1.8%
15–24 years	culprit		153.0	68.1%	2.3%
	participant	1511410	71.8	31.9%	1.8%
	total		224.8	100.0%	2.1%
25–60 years	culprit		367.2	59.9%	17.4%
	participant	4806188	245.8	40.1%	19.7%
	total		613.0	100.0%	18.2%
Above 60 years	culprit		232.6	54.6%	4.5%
	participant	1973556	193.4	45.4%	6.4%
	total		426.0	100.0%	5.2%
Total	culprit		980.4	62.8%	100.0%
	participant	10354842	579.6	37.2%	100.0%
	total		1560.0	100.0%	100.0%

The objective of my so far ten-year research project is to work out a model of behaviour during public transportation that makes it possible

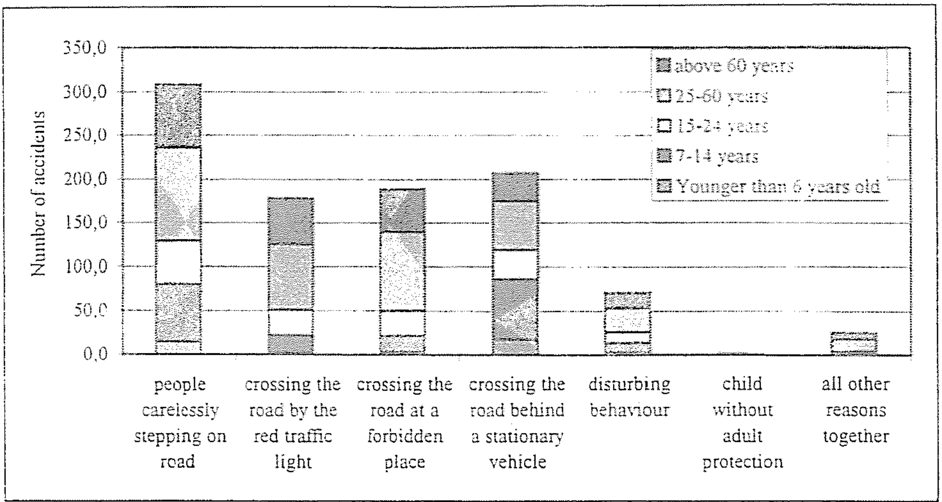

Fig. 1. The distribution of accidents caused by pedestrians, according to age groups

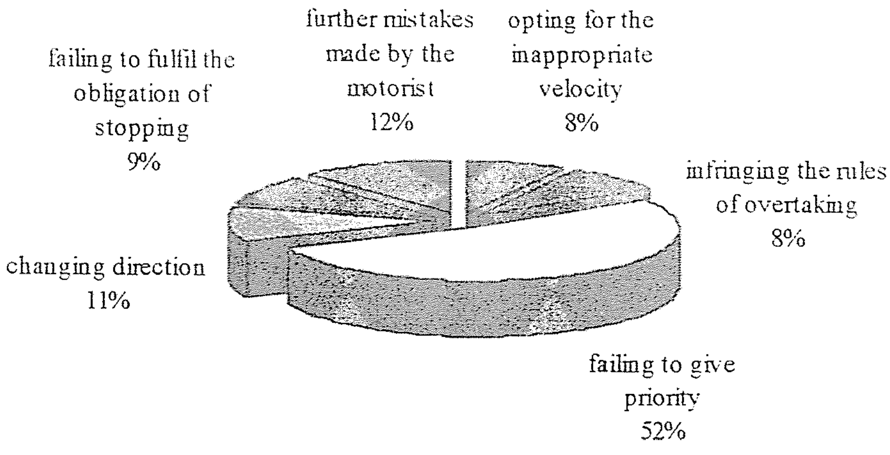

Fig. 2. The distribution of cases where accidents involving pedestrians have been caused by the motorists

to study and specify behavioural patterns and characteristic habits of participants in transportation. Throughout my work, I have drawn upon the experience of public transportation psychologists, as well as upon my and my colleagues' observations. It is my firm conviction that the possible improvement of conditions prevailing in public transportation primarily calls for a conscious change in the behaviour of participants involved in transportation, along with the introduction of technical equipment applied in transportation that is better adapted to the attributes of participants' transportation habits. This approach appears far more effective than exclusively and constantly modifying regulations in public transportation and acts of law in the Penal Code that threaten the public with punishment. The first and inevitable step towards implementing the above strategy is to get to know the behaviour patterns existing in public transportation, to which simulational modelling can be highly conducive.

2. The SIMPAS Transportation Simulational Model

SIMPAS (**Si**mulation du **Pas**sage Pièton) is a composite of a road traffic simulational model and a computer programme created for application in the analysis of public transportation. The elaboration of SIMPAS was commenced at the French research centre Institut National de Recherche sur les Transports et leur Sécurité (INRETS), which fact is reflected by the language in which the project has been named. Functioning as the basis for the model was ARCHISIM: a simulational model developed under the leadership of Stéphane Espié at the French research centre. The project SIMPAS was accomplished at the Faculty of Transportation Engineering at the Technical University of Budapest.

The basic assumption underlying the model is that traffic situations are from moment to moment determined by impacts mutually exerted by participants of transportation upon one another. Each and every participant of transportation is more or less an autonomous entity, endowed with his or her own characteristics and equipped at all times with an individual strategy designed for solving potentially arising conflicts and for realising his or her various private aims and aspirations.

The complexity of ensuing traffic situations springs, on the one hand, from the diverse nature of the participants' characteristic features, and, on the other hand, from the multifaceted nature of the contacts arising between participants.

In order to be able to simulationally model traffic situations, it is indispensable to identify the participants of the transport system, as well as to specify the data necessary for the description of the individual elements' function and behaviour. Model SIMPAS has developed from Model ARCHISIM, retaining and utilising its advantages and preserving its pivotal conception, according to which participants of public transportation communicate with each other [4]. As a consequence of this, an important phase during the development of the model is the definition of data that participants are capable of, on the one hand, radiating towards others, and, on the other hand, perceiving from their environment. Following this phase, it is possible to draw up behavioural models of the individual elements, containing guidance as to what alterations of position or state they will effect as a result of pieces of input information.

Model SIMPAS has been pre-eminently completed to facilitate the habits and tendencies of pedestrians and drivers of vehicles. Developing a working model of the pedestrians and the motorists' behavioural patterns consists of the subsequent three phases:

- specifying the pieces of information received by motorists and pedestrians,
- analysing the pieces of information received and used when making decisions, as well as drawing up external and internal criteria in line with the respective participants' characteristics,
- working out a model showing the crossing habits of pedestrians and the tendencies of motorists whether to give priority or not.

Specifying data employed during the development of the model occurred through analysis, using methods from transportation engineering and statistics, of pedestrian accidents in public transport, as well as through observations and the evaluation of video footage made at various pedestrian crossings and their immediate vicinity. The contribution of Hungarian professional publications [4] [5], alongside that of the results of INRETS transportation psychologists' scientific researches [2] [3] have been invaluable at the development of the model showing pedestrians' and motorists' patterns of decision-making and behaviour.

This computer programme makes not only possible that contacts ensuing between participants of public transportation can be studied and that the behavioural model of the participants is available for evaluation, but also enables the researcher to examine the flow of traffic at various pedestrian crossings equipped with different techniques of traffic control. Types of pedestrian crossings available for examination with the programme are the following:

- unmarked pedestrian crossing,
- designated pedestrian crossing,
- elevated pedestrian crossing,
- pedestrian crossing with an island in the middle,
- pedestrian crossing equipped with a push-button traffic-controlling device containing a light signal.

3. The Transportation Behavioural Model

The underlying conception behind the behavioural model is that all participants of the transportation process are independent, autonomous persons endowed with their own inner features. In the course of taking part in public transportation, they make decisions in knowledge of their personal objectives and the pieces of information perceived by them concerning the state of the traffic in their environment. Furthermore, their decisions are made on the basis of their own characteristics and momentary state of mind.

Every participant in public transportation constantly radiates data into its environment, and, simultaneously, receives data from its environment. The quantity and quality of received data are features characteristic of the participants of transportation. Therefore, when identifying members of the traffic, it is an essential requirement that pieces of information exchanged (radiated and received) by the participants be specified both with respect to quantity and to quality. In the case of pedestrians and motorists, establishing the set of data has been greatly helped by the treatises of transportation psychologists.

The internal workings of participants in public transportation consist of the subsequent three periodically repetitive phases (*Fig. 3*):

- perceiving pieces of information from the environment,
- forming a decision-making strategy on the basis of processed information and personal characteristics, together with the individual's objective(s);
- executing what has been decided.

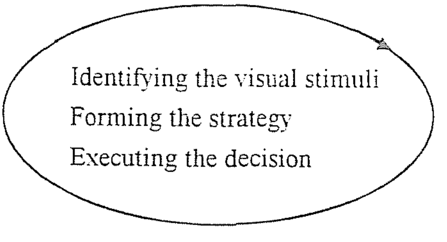

Fig. 3. Internal workings of participants in public transportation

In a given traffic situation, participants of transportation come to their decisions driven by their individual inner qualities and habits. Both motorists and pedestrians are individually characterisable in terms of what kinds of decisions they are inclined to make at a particular time, in a given traffic situation, taking into account their personal intentions, the traffic regulations and other aspects of public transportation. One can model the relationship of participants to traffic rules, to the other participants of transportation and to their own objectives by means of a decision triangle (*Fig. 4*).

At any particular moment, it can be established how much these components weigh in the individual participant's decision-making process.

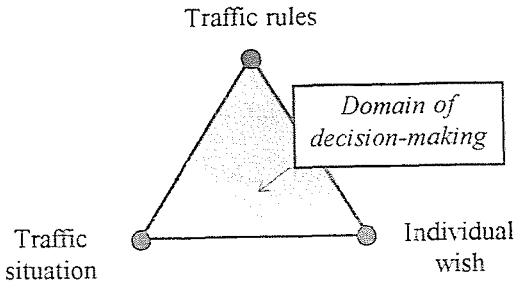

Fig. 4. Factors influencing decision-making by participants in public transportation

3.1. The Pedestrians' Model

When examining the behaviour of pedestrians, one needs to lay the greatest emphasis on and analyse in detail those cases that involve pedestrians crossing a road at another place than the designated pedestrian crossing, and ones where the pedestrian compels the motorist to give him or her priority by stepping prematurely onto the road surface. Regular and conflict-free crossings should not be analysed in respect to behavioural attributes, however, they make the examination of the flow of traffic possible.

When examining pedestrians' behaviour patterns, one predominantly expects to find an answer to the question of which human factors influence their decisions. Likewise, one looks for an answer to the query of 'in what way and with what weight do these factors take part in shaping one's strategy for action?' Answers to these questions provide clues to the understanding of people's transportation habits.

In the course of the simulational analysis, pedestrians can reach the road surface in question at any place they choose, and not only at the designated pedestrian crossings. To avoid complications, pedestrians' destinations are always to be found exactly opposite to the spot of arrival. When a pedestrian arrives at the road surface at another place than the designated pedestrian crossing, he or she is thereby forced to make a decision concerning the itinerary of crossing the road. He or she can opt for the shorter way, that is refrain from using the designated place for crossing the road, or decide in favour of the longer route and thus incorporate into his crossing itinerary the designated zebra (*Fig. 5*). This decision is constantly evaluated by the pedestrian on the basis of the traffic situation and his or her own inner characteristics. According to this, the movement of the pedestrians may follow the subsequent directions:

- they are awaiting the chance to cross the road at the kerb,
- they are at an intermediary location between both kerbs,
- they are approaching the designated pedestrian crossing by walking on the pavement,
- they are approaching their original destination spot on the pavement of the target side,
- they change their mind and, after the crossing has been attempted, turn back.

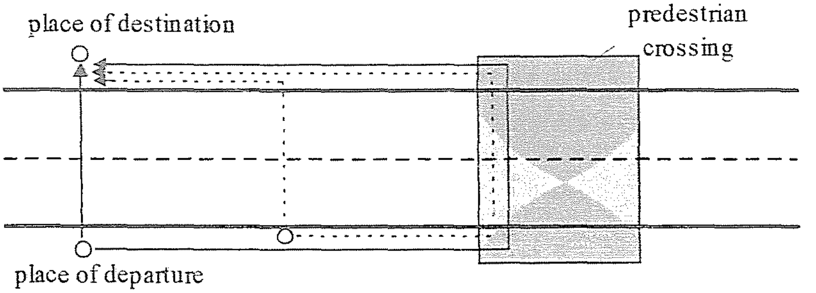

Fig. 5. Possible itineraries for crossing a road on foot

Pedestrians are grouped according to their age and members of the age groups are taken to have the same basic features relevant to the behaviour in traffic (e.g. speed, adherence to the rules, etc.). The age group boundaries indicated in the model coincide with those used in statistical lists.

4. Information Exchange between Pedestrians

In order to be able to create a strategy for decision-making, the perception, conscious intake and evaluation of information stemming from one's environment are indispensable. These pieces of information can be both primary and deduced ones. Pieces of information perceived by pedestrians, grouped according to their source:

Primary pieces of information:

- *Pedestrian crossing*
  - layout of the area in terms of the used traffic control technique
- *Vehicles*
  - category of vehicle
  - position

- attributes of movement
- signals

- *Pedestrians*
  - category of pedestrian
  - position
  - state of movement
  - operation

Deduced pieces of information:

- *Pedestrian crossing*
  - the degree of security
- *Vehicles*
  - quality of traffic
  - relative situation of participants
- *Pedestrians*
  - quality of traffic
  - relative situation of participants

Pedestrians, as all participants of transportation, emit information about themselves that can be perceived by the other participants. Kinds of information emitted by pedestrians are the following:

- category of pedestrian
- operation
- state of movement
- position

5. The Behavioural Model of Pedestrians

The possibilities of a pedestrian in respect to the relative position and state of movement of the approaching motor vehicle (*Fig. 6*) are the following:

- the vehicle passes in front of the pedestrian – there is no conflict situation,
- the pedestrian is unable to cross the road before the approaching vehicle,
- the pedestrian is able to cross the road before the approaching vehicle, provided it slows down,
- the pedestrian has the space to cross the road surface before the approaching vehicle arrives there.

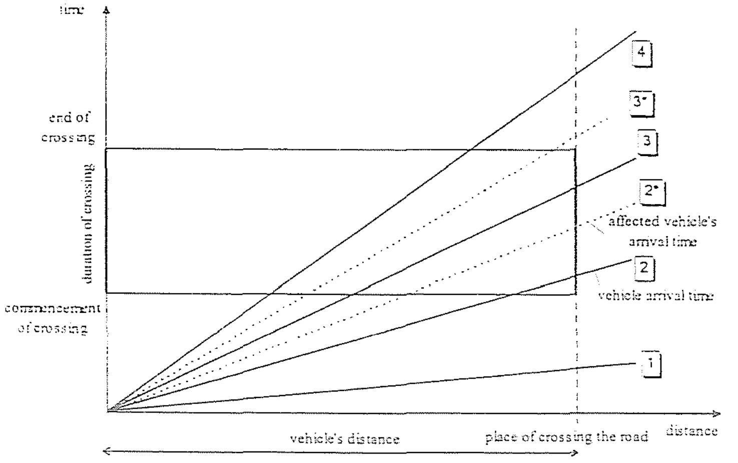

Fig. 6. Possibilities for a pedestrian to cross the road

Important cases are, from the point of view of the behavioural analysis, the ones where the pedestrian forces the approaching vehicle to slow down and the ones where the pedestrian does not make use of the designated place for crossing. Components determining the decision on the part of pedestrians whether to cross the road or not:

- the attributes of the pedestrian's state,
- the relative position of the pedestrian and the designated place for crossing,
- traffic rules,
- the degree to which traffic rules are adhered to by him or her,
- the momentary hazard of attempting to cross the road,
- the degree of security provided by the designated pedestrian crossing,
- the extent to which the pedestrian, at the moment, is prepared to take risks.

The above components are subject to continuous alteration depending on the inner characteristics of the pedestrian and the momentary conditions prevailing on the road.

Possible decisions:

- waiting for one's turn at the kerb
- approaching the pedestrian crossing on the pavement
- crossing the road
- approaching one's original destination by walking on the opposite pavement after crossing the road
- changing one's mind and turning back whilst crossing the road

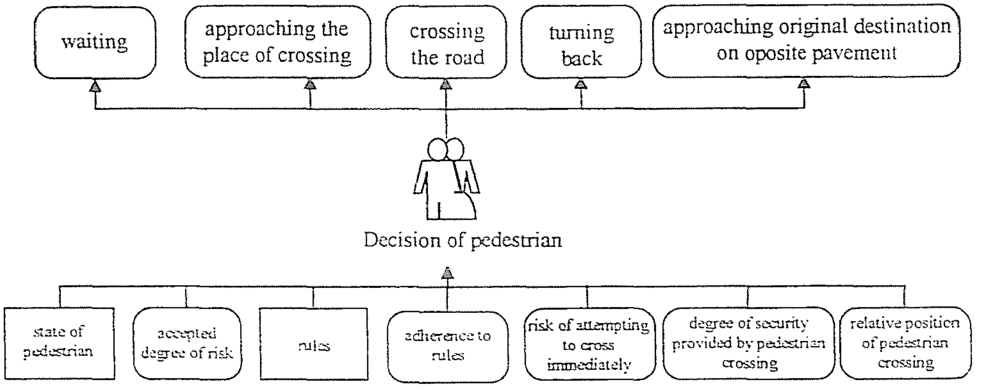

Fig. 7. Factors influencing pedestrians' decisions of how to cross a road

The risks inherent in crossing a road are in proportion to the length of the time for which the pedestrian's way and the vehicle's way meet each other. The examination of pedestrians' risk-taking while crossing roads is an important field of study within transportation psychology. Factors determining the degree of risk-taking, in connection with the attributes of the pedestrian's state are the following:

- the rate at which the pedestrian's initial risk taking inclination increases, as well as the degree of his or her initial risk-taking,
- the presumed amount of time necessary for reaching the place of destination,
- the cumulative time of impediment of the vehicle (i.e. time gained through the vehicle slobwing down).

5.1. *The Motorists' Model*

Motorists, while driving along the given section of the road, enter into contact with the other participants of transportation. These contacts exert their effect on the motorists and on the time their drive takes. The objective of the motorist is to cover that particular section of the motorway in the time he or she expected it to take and his or her expected progress is hindered by the other participants of traffic to a lesser or greater extent.
The vehicle may proceed:

- on its own, undisturbed,
- in a chain of vehicles under the direct influence of the preceding vehicle,
- influenced by a pedestrian crossing the road or preparing to cross the road,

- under the influence of the push-button operated traffic controlling device.

Model SIMPAS does not examine the contacts between motorists, since, in the immediate proximity of pedestrian crossings, overtaking and changing lanes, as well as other similar operations are forbidden by traffic rules.

6. The Information Exchange between Motorists

Just like to pedestrians, the exchange of information with the environment and communication with it are indispensable for motorists' decision-making process, too. Primary kinds of information, along with deduced pieces of information coincide with the ones pedestrians perceive. Types of information radiated by vehicles are as follows:

- type of vehicle,
- momentary position and direction of movement,
- momentary velocity and rate of acceleration.

7. The Behavioural Model of Motorists

The potential decisions on the part of motorists concern the modification of the vehicle's rate of acceleration. The main internal and external factors influencing motorists' such decision-making process are the following:

- the estimated time required to cover the whole section of the road,
- the time wasted in relation to the estimated duration of the drive,
- the momentary state of movement of the vehicle,
- the desired velocity,
- the degree of accepted risk-taking,
- traffic rules and the motorist's level of compliance with them,
- pedestrian traffic,
- vehicle traffic.

The values of the above listed factors of decision-making are subject to continuous alteration depending on the inner characteristics of the motorist and on the momentary state of the traffic.

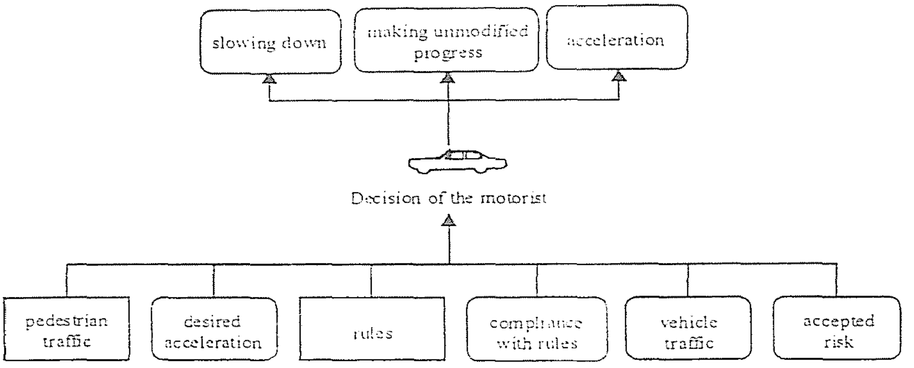

Fig. 8. Factors influencing the decisions of the motorist

8. The SIMPAS Traffic Simulation Model

The SIMPAS traffic simulation model makes full use of the results of Model ARCHISIM. This is reflected by the structure of the model, although the possibility of efficiently examining pedestrians' behaviour patterns is the sole merit of Model SIMPAS.

Analyses that have become possible thanks to the model can be arranged into two basic groups:

- analysis of the participants' behaviour,
- scrutiny of traffic on the roads.

SIMPAS has enabled analysts to compile a database by recording the state of traffic at each step of simulation. Furthermore, with SIMPAS, there is a free choice concerning parameters of participants of public transportation and of the traffic.

In the course of the simulation analysis, the flow of traffic can be visually observed and the speed of the calculations can be accelerated or retarded, as well as stopped at the required moment, in which latter case, the attributes of participants' momentary states can be displayed on the screen.

8.1. *The Model of the Road Network*

Model SIMPAS has not been developed with the intention of examining the traffic of road networks, instead, it is designed to facilitate the analysis of the traffic along one particular section of a road. As a corollary, the model of the given section of the road is one single graph. The positions of the individual elements of transportation can be unequivocally established in relation to the graph, with the help of vertical and horizontal coordinates and of the direction of progress (*Fig. 9*).

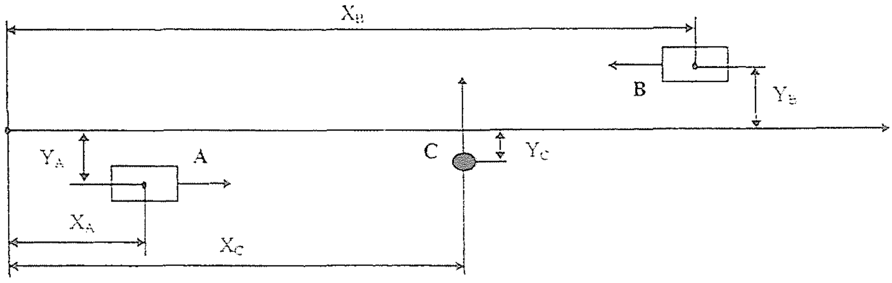

Fig. 9. The distribution of participants of transportation in the graph

8.2. The Internal Structure of the Model

The structure of the classic transportation simulation models consists of two main components: data concerning the momentary state and qualities of participants in transportation and a controlling procedure. The algorithm supervisor contains all those relationships for each element taking part in the model, on the basis of which it establishes the next state of the elements of the system. All features of each element are exactly familiar to the procedure, which is thereby capable of calculating the forthcoming changes in the state of those (*Fig. 10*).

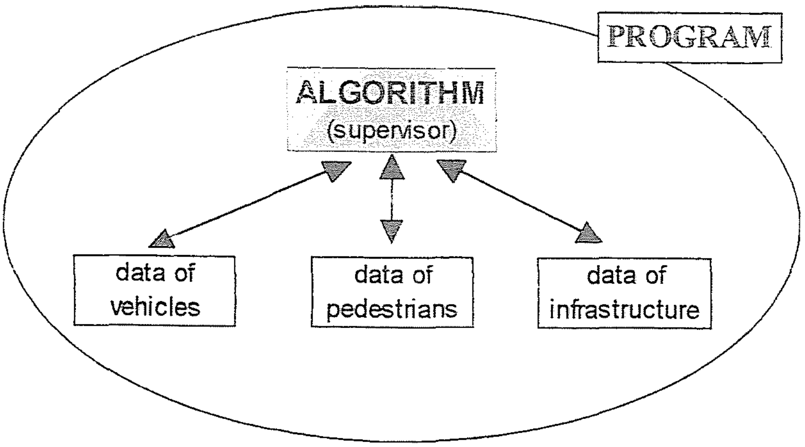

Fig. 10. The structure of classic simulation models

As opposed to these classic-type models, models ARCHISIM and SIMPAS are not equipped with a central control. Instead, in the case of these models, participants of public transportation possess their own independent characteristics of habit, are able to receive pieces of information radiated towards them from their environment (only data that are actually perceivable in real-life situations), following which they can make their individual decisions and shape their states of movement independently. The environment renders communication between the parties possible (*Fig. 11*) [6].

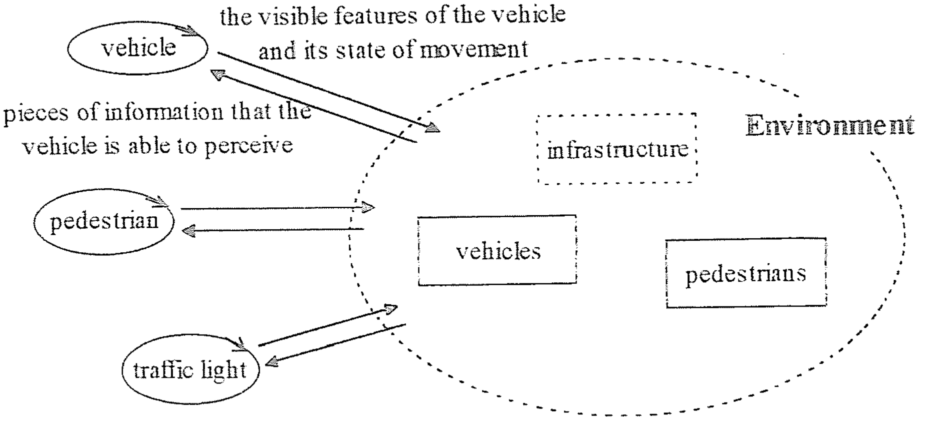

Fig. 11. The structure of Models ARCHISIM and SIMPAS

9. Summary

Model SIMPAS enables for the analyst to study by simulation the behaviour of participants in public transportation and the flow of traffic in the proximity of pedestrian crossings.

The underlying conception of the model is that momentary situations in public transportation are directly dependent upon the impacts participants of transportation make on one another. Elements of transport communicate with each other, and come to their decisions independently, on the basis of their own inner characteristics and of pieces of information they receive from their environment. The primary objective motivating development of the model is the analyst's getting to know the behavioural patterns of the participants.

The open structure of the simulation model ensures the simple integration and study of different hypotheses along with behavioural and decision-making models.

The computer programme based upon the model is capable of recording by simulation steps the events and the participants' momentary states. The size of the intervals employed in the simulation is a parameter that can be altered according to the type of participants engaged in transportation. The collection of data takes place in a format comprehensible for Microsoft Excel, which makes the processing and analysis of the collected data rather simply.

Acknowledgement

The development of the transportation simulation model SIMPAS has been conducted in close cooperation between the French transportation research institute INRETS and the Faculty of Transportation Engineering at the Technical University of Budapest. The cooperation has been made possible by a three-year scholarship donated by the French government. Therefore I would like to express my thanks to the French Institute in Budapest and to the employees of CROUS for their successful organisation of the scholarship.

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