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THE APPLICATION OF DETECTORS IN DETERMINING THE SAFETY INTERVALS AT INTERSECTIONS WITH TRAFFIC LIGHTS

SUMMARY:

The paper presents a model of a detector-controlled traffic light intersection as a complex traffic system. By analysing the key factors of safety, the preliminary guidelines are given for the implementation of the presented solution. The special emphasis is on defining the safety intervals as significant safety factors in passing through an intersection.

1. INTRODUCTION

The development of the modern society is trying every day to shorten the physical distances between people by developing increasingly sophisticated technical aids. The consequences can be seen in the increasing level of motorisation and automobilisation of the society, necessarily leading to the increasing complexity of the traffic system conditions.

The trend is also present in the Republic of Croatia. Between 1986 and 1990 the traffic on the public roads outside the cities grew on the average by about 6.5%, and the number of registered passenger cars about 4.5% annually[1].

On the other hand, modernisation and improvement of the roads do not follow the motorisation conditions, thus resulting in the reduced road traffic safety as an essential factor of the traffic system quality of every country.

Reduction in safety of the road traffic users is indicated by the increase in the number of traffic accidents. The following data refer to the occurrences at intersections of the Croatian road network, annually, on the average[2]:

- 20% of all the registered accidents;
- 20% of all the traffic injuries belong to these accidents;
- 10% of all the fatalities in traffic happen here.

Similarly, the statistical data indicate that the majority of traffic accidents happens within the settlements. So, at the Zagreb intersections annually occur on the average[2]:

- 40% of all the registered accidents in the city;
- 45% of all the injured in the Zagreb city traffic get injured here;
- 30% of all fatalities in the Zagreb city traffic happen here.

The traffic regulation at the intersections is therefore of utmost significance for the road traffic safety in general.

City intersections are places of conflicting paths of numerous traffic participants: vehicles, pedestrians, cyclists, trams and others. The intersections are therefore, such as they are, complex traffic systems, the construction of which requires both from the point of view of civil engineering and from the organisational aspect great attention, with the aim of increasing the safety of the road traffic participants.

2. TRAFFIC REGULATION USING LIGHT SIGNALS

Traffic can be regulated in various ways. The aim of regulation is to bring the road traffic users over the shortest time and in the safest way to the final destination by adequate co-ordination of traffic flows.

Since numerous different traffic flows meet, and very often collide at the intersection, there is a need for adequate traffic regulation, especially in the urban areas. In conditions reflecting the complex traffic systems such as city intersections, the regulation is very often done by traffic lights.

The traffic flow features are magnitudes of explicit stochastic character. It would be wrong to think that the traffic light regulation shortens the passing times of the road traffic participants through the considered traffic network. On the contrary, regulation by traffic lights stops the traffic flow at the point where it collides with the other traffic flows, thus making the passing time of the considered network throughput volume longer. The ideal case would be "regulation-free regulation". However, considering the complex character of the intersection, the application of traffic lights in traffic regulation of the intersection, mainly in peak hours, provides the optimal solution.

2.1. Methods of regulating the traffic light intersection

At the intersection traffic can be regulated in the following ways:

- manually
- time constant,
- semi-dependent, and
- dependent on traffic.

Manual regulation is most frequent at under-sized intersections at peak loads, or in similar atypical circumstances. It is extremely expensive and inert, and has sense only if it is applied over shorter periods of time.

Time constant regulation is applied according to the previously given programme, devised on the basis of traffic count i.e. appropriate traffic predictions. This kind of traffic regulation is characteristic for technologically obsolete, mainly relay regulation devices.

Semi-dependent regulation assumes that there are two phases which are different in their significance. The traffic flow of the main phase is regulated according to the time constant regulation programme, and the secondary phase is regulated only with the previous detector identification.

Traffic dependent regulation is the best method of traffic regulation at the traffic light intersections. Such regulation organisation makes the intersection a complex system with all the appropriate characteristics. These include, first of all, the introduction of a certain kind of feedback which transmits the necessary information by means of adequate measuring instruments (sensors, TV cameras, GPS) to the control unit (computer), in order to optimise the traffic lights regulation process.

2.2. Regulation by induction detectors

Detectors have found a wide scope of applications in traffic, ranging from traffic count, automatic parking ramps, to registering the entrance of road users into the traffic.

Today, numerous different types of detectors are being used, which obviously causes the absence of a universal technological solution for detector design in traffic regulation. This makes detectors a critical subsystem in the traffic control process.

Here is one of the possible classification of detectors:

- detectors (buttons) for pedestrians, and
- detectors (inductive loops) for vehicles.

Of all the types of detectors for registering the passing and presence of the traffic participants, the inductive detectors have proven to be the most suitable ones.

2.2.1. Vehicle detectors

At isolated intersections, the traffic is usually regulated by using the detectors of passing and the detectors of sensing the presence i.e. the so-called short and long inductive loops (Figure 2.1). They are embedded in the roadway surface at the depth of about 10 cm, and they are connected with the appropriate detector units. Exceptionally, when the roads are very narrow, there is the risk that a detector could incorrectly register the opposing traffic, in which case the so-called detectors of direction are used.

The detectors of passage register every passing of the vehicle. Since their sensitivity may be adjusted, they can register the passage of various vehicle categories. They are located at the distance of 20-70 m from the "stop" line, over one or more traffic lanes [3]. The detectors of passage are the re-balancing ones, which means that vehicles stopping at the detector loop will be registered with one impulse. Every subsequent vehicle passing along the free part of the loop will be registered independently.

The detectors of sensing the presence at the loop register the stopped vehicle by a non-rebalancing impulse. They are usually located, according to [4] on the very stop line, or at a distance of 10 m, whereas the length of the loop depends on the specific features of the considered intersection.

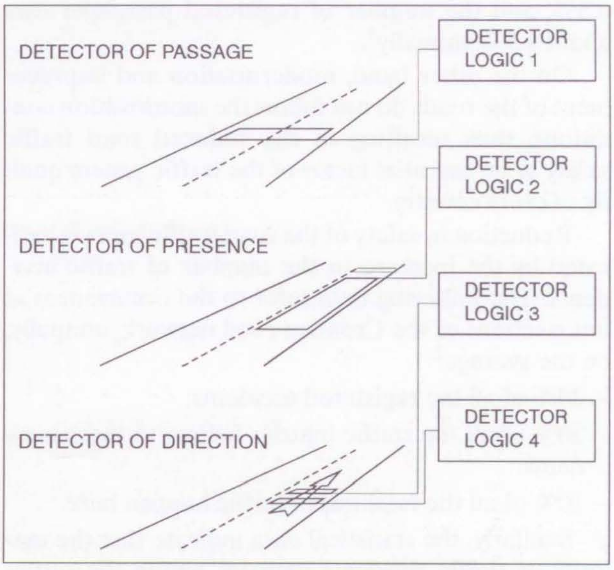

Figure 2.1 - Designs of inductive detectors

Table 2.1. Significant advantages and drawbacks of various detector designs

	ADVANTAGES	DRAWBACKS
SHORT INDUCTIVE LOOP	– timely identification eliminates the unnecessary stopping of the traffic in case of lower traffic intensity – smaller losses of the green indication – measuring of the time interval between vehicles as a criterion for lengthening is relatively independent on the vehicle speed	– more difficult estimate of the requirement for the green signal notion, especially with greater distances between the detector and the stop line
LONG INDUCTIVE LOOP	– it is not necessary to calculate additional times since every vehicle on the detector requires lengthening as long as the detector loop is busy – differences in seasonal driving conditions do not influence the operating of the detector	– due to relatively late identification, the vehicles have to stop or substantially reduce their speed – the prolongation is maintained until the physical distance between two vehicles exceeds the length of the detector loop, and the distance cannot be changed without using the time interval – due to their non-rebalancing character, the detector cannot recognise a parked vehicle.

Significant advantages and drawbacks of the mentioned detector design for vehicles are given in Table 2.1.

By combining the detectors of presence and those of passage in the regulation of traffic lights intersection, the drawbacks of each of individual designs are compensated.

The traffic lights regulation model of the considered intersection V. Holjevca Ave. and Dubrovnik Ave. requires the application of the combined detectors for identification.

3. THE CHARACTERISTICS OF THE DUBROVNIK AVE. - V. HOLJEVCA AVE. INTERSECTION

3.1. Characteristics of the intersection construction design

The current engineering solution of the considered intersection together with the collision points are given in Figure 3.1.

The considered intersection is of rectangular type with the following features:

- 3 lanes each in direction *east-west*
- 2 lanes for taking a left turn in direction *west-north*, i.e. 1 lane for taking a turn direction *east-south*
- 2 lanes each in direction *north-south*
- 2 lanes for taking a left turn in direction *north-east* i.e. 1 lane for taking a turn *south-west*
- tram line *east-west*
- 1 lane each for turning right
- pedestrian traffic is organised at the same level as the vehicle traffic

All these data indicate that the considered intersection is of an extremely complex nature with a great number of participants.

Therefore, a much safer and more efficient solution for this intersection would be to separate the levels of the traffic flows. Since substantial material investments would be necessary for such an engineering solution, then the improvement of traffic signalling by introducing the detector-controlled traffic lights regulation offers an optimal solution in controlling the traffic system.

3.2. Safety features

It is impossible to define the criteria for evaluating the traffic safety conditions without any ambiguities. Therefore, these are formed in accordance to the specific features of the considered segment of the traffic system. The quantitative indicators for evaluating the traffic safety conditions rely on quantitative safety indicators, thus providing the most objective criteria for traffic safety evaluation. It is often very difficult to obtain the quantitative indicators in real conditions, and their absence tends to be compensated by introducing qualitative, subjective indicators.

In case of the intersection, the most adequate traffic safety indicator is the relation of the number of accidents or their consequences, and the number of vehicles passing through the intersection.

The collision points at the considered intersection are presented in Figure 3.1, and can be interpreted as:

- collision while changing lanes

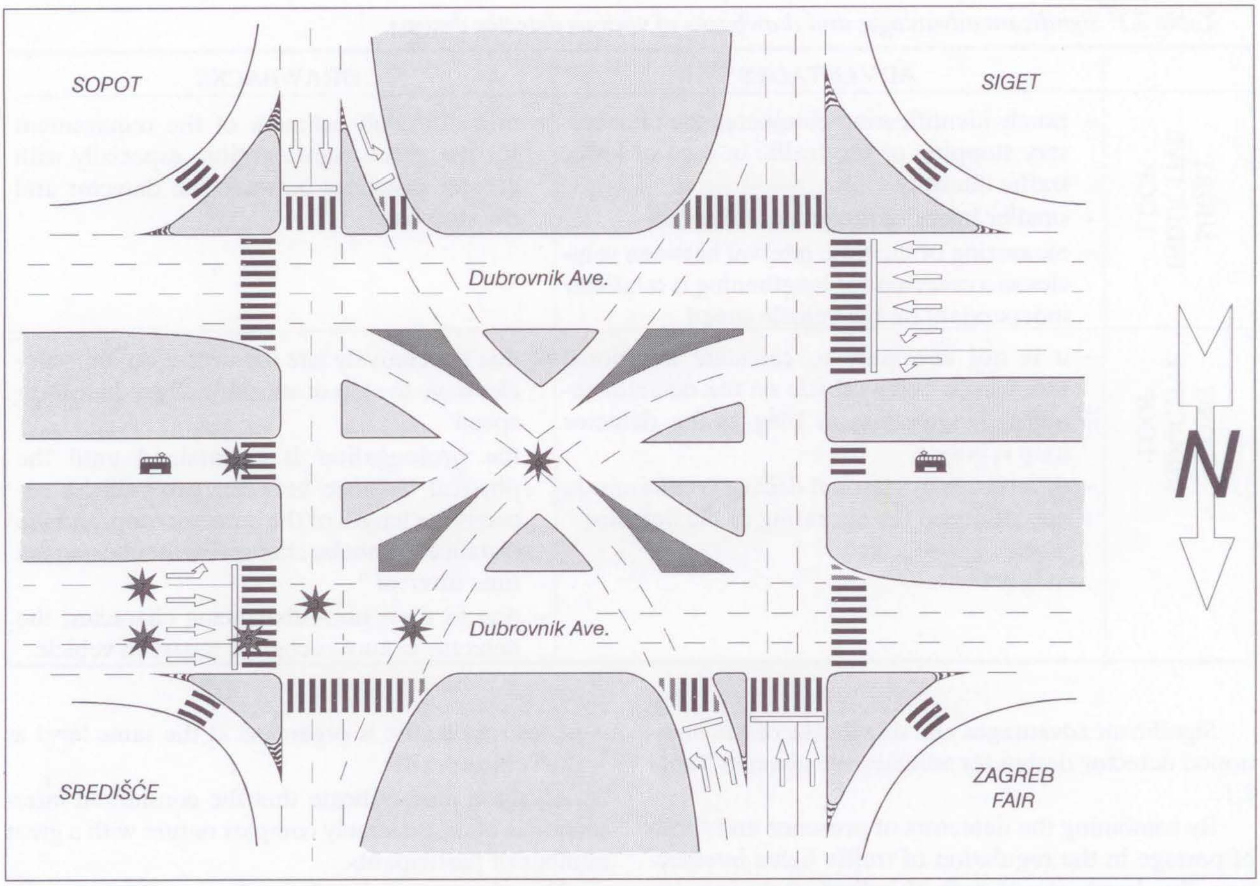

Figure 3.1 - Intersection V. Holjevca Ave. - Dubrovnik Ave.

- tram-pedestrian collision
- collision due to non-compliance with the right-of-way
- vehicle crashing into the vehicle in front
- vehicle-pedestrian collision
- tram-vehicle collision

The number of traffic accidents at this intersection between 1981 and November 1997 are presented in Table 3.1, i.e. graphically in Figure 3.2 [5].

Table 3.1 - Statistical safety indicators for the considered intersection

Year	Number of Accidents	Number of Fatalities	Number of the Injured
1981	54	–	20
1982	47	–	48
1983	29	–	29
1984	4	–	20
1985	53	–	30
1986	23	–	10
1987	31	–	14
1988	20	2	5
1989	46	–	6
1990	45	–	20
1991	45	–	23
1992	58	–	14
1993	40	–	17
1994	33	–	14
1995	49	–	14
1996	64	–	11
Nov. 1997	59	–	6

There is a noticeable fall in the number of accidents in 1986 due to the reconstruction of the intersection. The lack of quantitative indicators can be compensated by the qualitative judgement that the increase in the traffic intensity (primarily of the number of vehicles using this intersection) has been the reason for a substantial increase in the number of accidents since 1989 to the present.

Since the considered intersection has already been reconstructed with the objective of increasing the traffic safety, and there is no use in talking about a new reconstruction, the introduction of traffic controlled

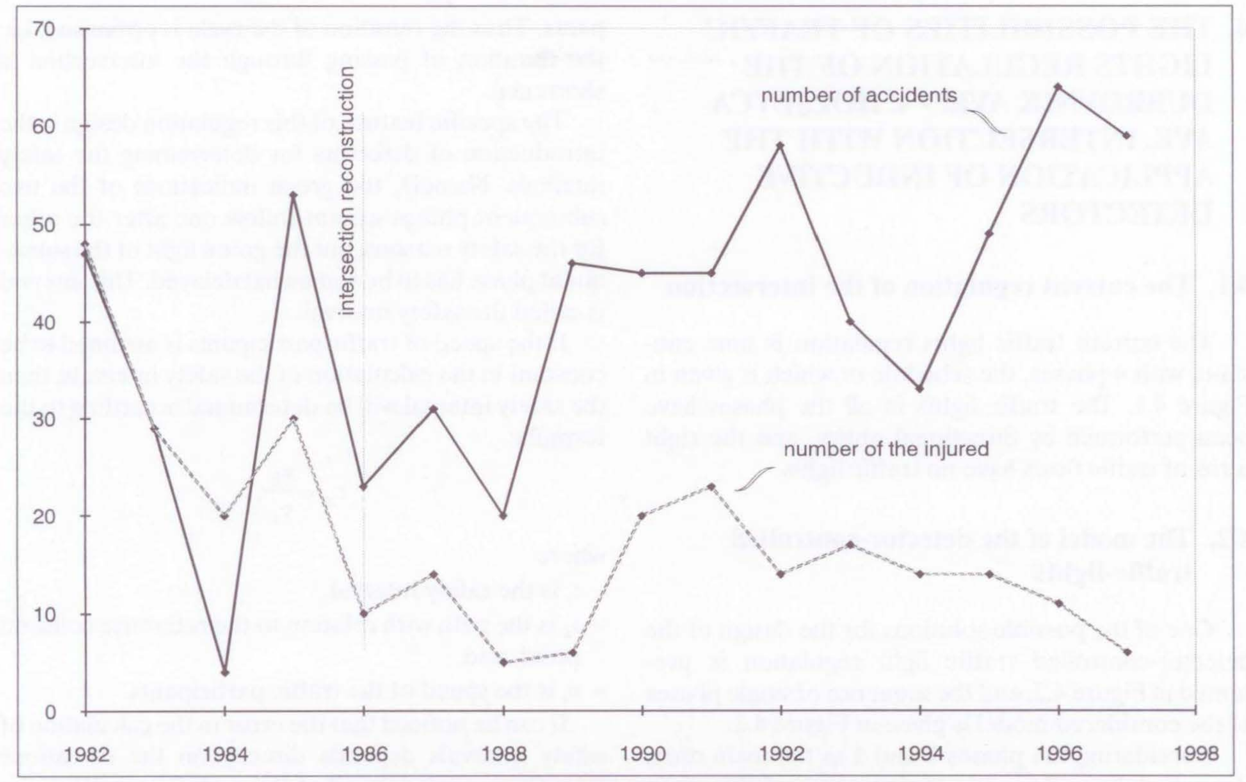

Figure 3.2 - Traffic accidents between 1982 and 1997

traffic lights regulation seems to provide an optimal solution, both from the point of view of increasing the safety, and of reducing the duration of passing through the intersection.

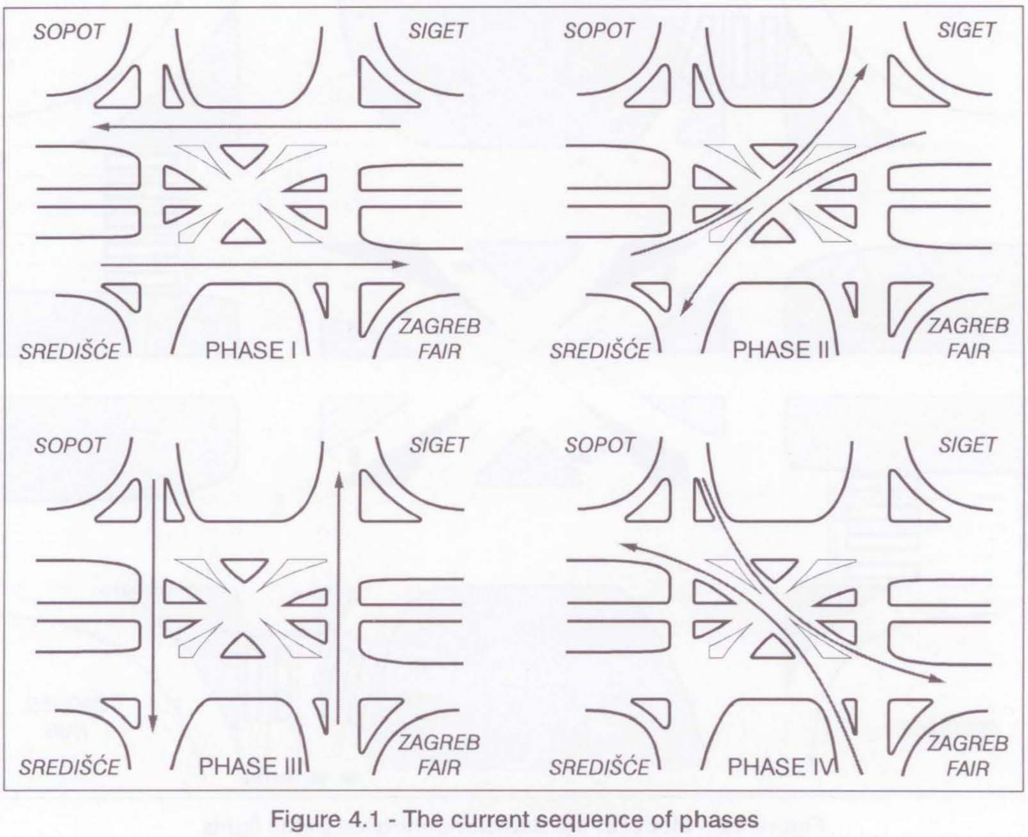

Figure 4.1 - The current sequence of phases

4. THE POSSIBILITIES OF TRAFFIC LIGHTS REGULATION OF THE DUBROVNIK AVE. - V. HOLJEVCA AVE. INTERSECTION WITH THE APPLICATION OF INDUCTIVE DETECTORS

4.1. The current regulation of the intersection

The current traffic lights regulation is time constant, with 4 phases, the schedule of which is given in Figure 4.1. The traffic lights in all the phases have been performed by directional optics, and the right turns of traffic flows have no traffic lights.

4.2. The model of the detector-controlled traffic-lights

One of the possible solutions for the design of the detector-controlled traffic light regulation is presented in Figure 4.2, and the sequence of single phases of the considered model is given in Figure 4.3.

Considering the phases 2 and 4 as the main ones, this scheduling allows the prolongation of the green light at the expense of the secondary ones, in accordance with the requirements of the traffic participants. Thus the duration of the cycle is optimised, i.e. the duration of passing through the intersection is shortened.

The specific feature of this regulation design is the introduction of detectors for determining the safety intervals. Namely, the green indications of the two subsequent phases cannot follow one after the other for the safety reasons, but the green light of the subsequent phase has to be somewhat delayed. This interval is called the safety interval.

If the speed of traffic participants is assumed to be constant in the calculation of the safety intervals, then the safety interval will be determined according to the formula:

$$t_z = \frac{s_k}{v_s},$$

where

- t_z is the safety interval,
- s_k is the path with relation to the reference collision point, and
- v_s is the speed of the traffic participants.

It can be noticed that the error in the calculation of safety intervals depends directly on the deviations from the assumed speed of the participants. With the increase of the intersection dimensions, these deviations grow. Since the considered intersection belongs

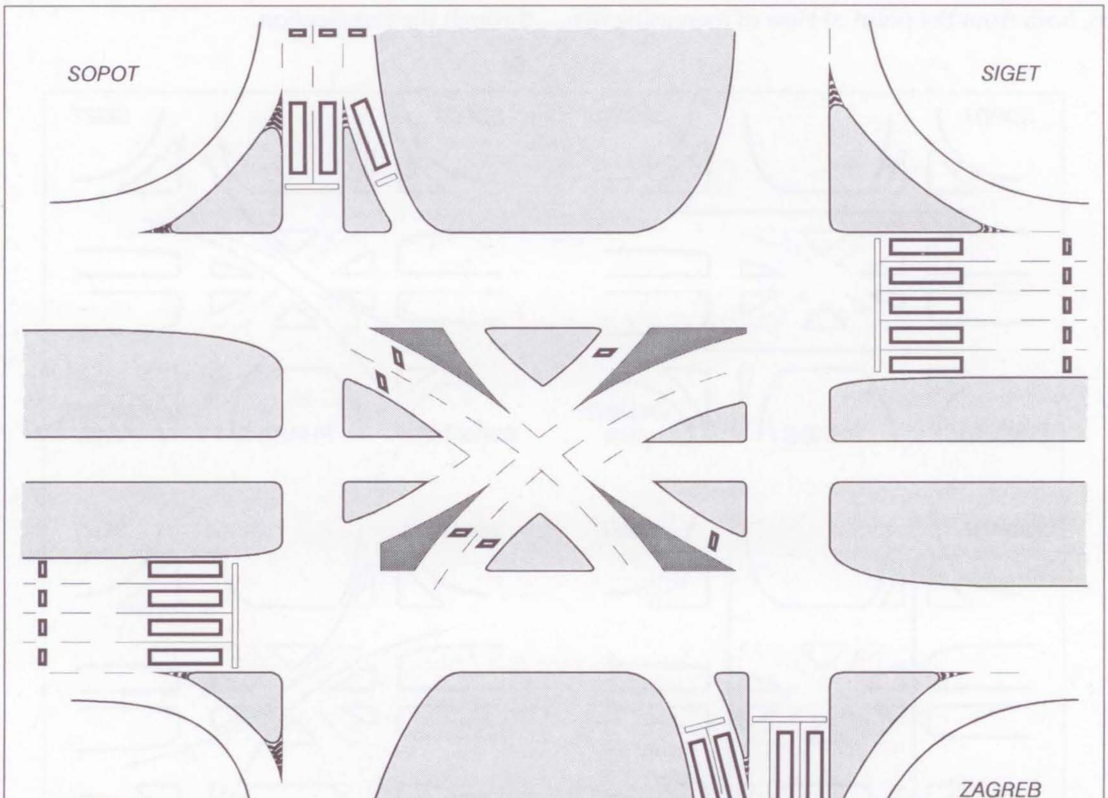

Figure 4.2 - Model of the detector-controlled traffic lights

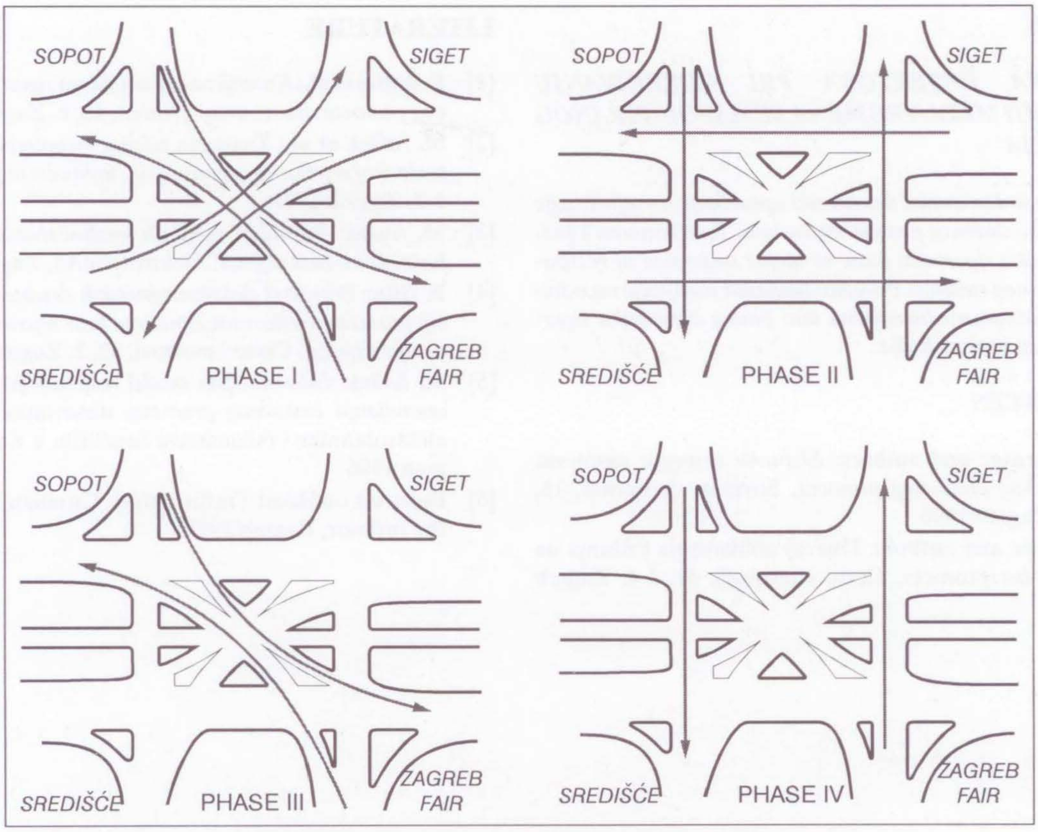

Figure 4.3 - Preliminary design of the sequence of phases

to the group of dimensionally bigger intersections, the introduction of detectors for determining the safety intervals seems justifiable.

The design of detectors for determining the safety intervals can be the following:

- detectors of speed
- detectors for notification

In the former, the estimated speed is the actual speed in relation to which the safety time interval is determined. In the latter, the detector for notification has the same role as with the dimensionally smaller intersections, but its positioning even within the intersection itself shortens the path according to which the speed of participants needs to be assumed, thus substantially reducing the deviations from the actually required safety interval duration.

It has to be noted that the presented model neglects the detector determining of the safety intervals between the phases *II* and *III*, as well as between the phases *IV* and *I*. However, due to the rectilinear character of the preceding phases (*II* and *IV*), and due to the fact that the phases *II* and *IV* pass along the shortest possible paths through the intersection, the assumed length of the safety intervals of the given phases will not deviate significantly from the actually needed lengths obtained by detector application.

5. CONCLUSION

In accordance with the considerations given in item 2, there are numerous possibilities for managing the traffic flows through the intersections, i.e. for the traffic light regulation. The paper presents one of the possible solutions, and the justification of its introduction is neither commented nor analysed. Since it would prove quite difficult to analyse the considered as well as similar models in real conditions, the final decision on the justification of their application can be obtained only by using certain simulation procedures which would provide the basis for comparing the possible savings in times which are needed to pass through the intersection i.e. the intersection safety indicators with the material investments for the reconstruction of the intersection.

In order to make the development of the simulation model for the considered intersection design possible, it is necessary to know the quantitative indicators of the traffic intensity. These indicators can be obtained by recording the characteristic segments of the real model, i.e. by traffic count. Due to their drawbacks, the justification of introducing the presented solution of the traffic light regulation has not been analysed, but it can certainly form the basis for further considerations in this field.

SAŽETAK

PRIMJENA DETEKTORA PRI ODREĐIVANJU ZAŠTITNIH MEĐUVREMENA SEMAFORIZIRANOG RASKRIŽJA

U radu je dan model detektorski upravljane semaforizacije raskrižja kao složenog prometnog sustava. Rasčlambom ključnih čimbenika sigurnosti dane su idejne smjernice za realizaciju prikazanog rješenja. Poseban naglasak stavljen je na određivanje zaštitnih međuvremena kao bitnog čimbenika sigurnosti prolaza kroz raskrižje.

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