

BEHAVIOR OF THE DRIVERS AT THE SEMAPHORED CROSSROADS WITH AND WITHOUT BLINKING GREEN LIGHT BEFORE IT TURNS INTO THE AMBER, Mladen Gledec

Police Academy

Zagreb

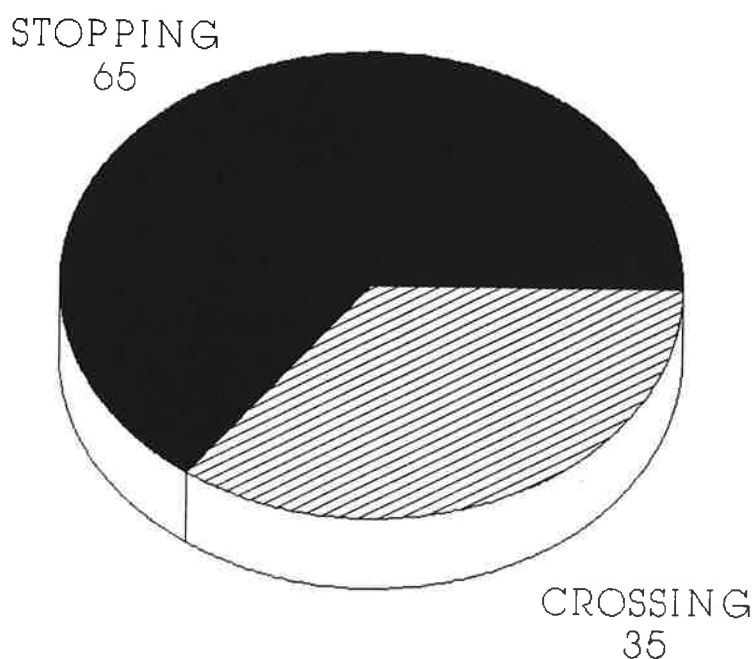
1. Ideal situation

An ideal situation when approaching the semaphored crossroads would be a division of the approach, when the amber turns on, into two zones:

- ♦ zone of passing, and
- ♦ zone of stopping.

A vehicle which, at the moment when the amber turns on, found itself in the zone of passage, will pass the crossroads, but the vehicle which is in that moment in the zone of stopping, will stop before the crossroads. In this ideal situation probability of stopping the vehicles when the amber turns on is a discrete function shown in the following Figure.

Figure 1: *Blinking Start (%)*, Becker (Israel Study)



All vehicles that are, at the moment when the amber turns on, away from the crossroads more than a length "a", will proceed driving on and will pass through the crossroads. Vehicles that are, in that moment away more than the length "a", will start braking and will finally stop before the crossroads.

But, such an ideal situation cannot be realized because the drivers approach the crossroads with different speeds and the process of making a decision, like all other human characteristics, is not in its nature discrete and deterministic but rather continuing and probabilistic.

2. What could the situation be?

For example, the following chart demonstrates what could be the driver's reaction when the amber turns on.

Every curve in this Figure presents a function of probability to make a decision to stop a vehicle, for a specific approaching speed, at various distances from the stop-lines. Thus, a mixture of interrelations between decisions to stop a vehicle and those to pass through the crossroads can be established for each separate distance. A point which the drivers find the most difficult to make a decision at, and therefore the point that shows a high rate of disparity in their choices, is the point at which 50% of drivers make decision to stop the vehicle, and 50% of them make a decision to pass through the crossroads.

The area that runs from the point at which 10% of drivers stop to the point at which 90% of drivers stop, is usually defined as a ZONE OF INDECISION.

When the problem of the zone of indecision is considered from the traffic-engineering point of view, then the primary interest is focused on the speed of a vehicle when approaching the crossroads, that is, on the length of its stoppable way.

This Figure shows a curve of the stopping distance of a vehicle as a function of the speed (without the way of reacting, with a minimal coefficient of friction which is 0,18).

Beside the curve of the stoppable way, this Figure shows the distances passed by a vehicle during the amber, that lasts 3, or 6 seconds. All three curves together define two different zones in approaching the crossroads:

- ◆ zone of dilemma (choice between two fires), and
- ◆ zone of option.

In the zone of dilemma, (which, in this Figure, exists only in a case when the amber lasts 3 seconds), a driver is faced with a choice between two unpleasant possibilities:

1. to apply severely the brakes, risking to stop the vehicle behind the stop-line at the crossroads, or
2. to continue driving (with an increased speed), risking to pass the stop-line through the red traffic light.

In the first case, the risk to cause a rear-end collision is larger than the risk in the second case to cause the side collision of the vehicles. The safety and the formal-legal problems of the “dilemma zone” could be solved by a prolonged duration of the amber, for more than usual 3 seconds.

3. What is the situation?

How does it look like in practice? For example, at the crossroads in populated areas, where the speed limit is 50 km/h?

If the approaching speed to the crossroads is not higher than 50 km/h, and if an appropriate magnitude of slowing down (namely, the friction) that could be realized at the stopping action, and on wet, and especially, on dry pavement, is 3 m/s^2 (on a square second), in that case, when the amber turns on - in duration of 3 seconds - all vehicles which at that moment were more than 30 to 35 meters away from the crossroads, should start braking and stop before the crossroads. However, those vehicles, which at that moment are closer to the crossroads than 30 m, should not decrease their speed, but should continue driving and should pass through the crossroads during the time the amber is on.

(For slower vehicles, this “critical” distance is, of course, smaller, while for faster vehicles, it is larger).

Above mentioned request of a legal nature, and in that aspect, is quite definite and clear-cut. Namely, the law on the traffic safety, where the role of the amber is defined, provides the following:

“when the amber autonomously turns on, it means that a vehicle must not either cross the stopping line, nor enter the crossroads, if at the moment when the amber turns on, it approaches the traffic lights with such a speed that can guarantee the safe stopping.”

As distinguished from this, it is less clear how the drivers should behave at the blinking green light, in those places at which the green light ends in this way. Namely, the legal provision defines the following: “The blinking green light serves to warn participants in traffic that the free passage is about to end and that the amber is about to turn on, that is, on the red traffic light”, and it does not imply any specific form of the drivers behavior, except that, at such spots, a slightly reduced time of the drivers reaction when the amber turns on should be expected.

Based on legal definitions it must not be concluded that the blinking green light has the same role as the amber light has, because when the blinking green light turns on, the drivers are not legally obliged to stop their vehicle in front of the crossroads, unless they are, at that moment, at a distance which insures a safe stopping. If, under conditions similar to those previously mentioned - they drive with a speed of 50 km/h and a distance from the crossroads is at least 30 to 35 m - and during the time when the amber is on, that is, during the blinking green light of 3 seconds, if the driver would begin stopping his vehicle at the

moment the green light begins blinking, then the vehicle would stop in front of the crossroads well during the duration of the amber - about 1,5 second before it would turn off.

The question is, to what degree the legal request is respected in practice, and to what extent, that is, whether the degree to which it is respected is influenced by the blinking green light, and how?

This question is not easy to answer. In order to answer it, it would be necessary, for each separate vehicle at the same time, to establish its speed and its distance from the crossroads, at the moment when the amber turns on; then, it would be necessary to establish the drivers reactions, in terms whether they changed or not the speed of their vehicle.

The only way to answer precisely and reliably this question should be through a thorough spacial-time analysis of movement of each vehicle, which is almost impossible to perform but through the computerized image processing technique.

However, if we are looking for rather qualitative than quantitative nature, some more simple techniques can be used as well. For example, qualitative comparison on a sample of randomly chosen real traffic situations.

What is a common behavior of drivers at the crossroads at which the green light ends with BLINKING?

As it can be seen, when the green light starts blinking, virtually there is no any visible reaction of the drivers, and frequently they do not react even when the amber turns on, although it should not be so.

If this reaction to the amber is late, it is motivated by a "strong parallel sources of information", that could be a policeman standing in the area of the crossroads, perceived at the last moment, which can be rather dangerous in that case!

But, this is obviously a specific case, instructive in another sense, showing us that the "parallel strong sources of information" should never be set at the crossroads, especially not if they are partly covered.

In some cases, except the fact that reaction to the amber failed to take place, reaction to the red light fails to come, ... therefore the drivers enter the crossroads during the first, ... and even during the following second of the red light.

In rare situations the drivers react even on the green blinking light, but these are mainly the cargo vehicles drivers.

However, this can be very dangerous because it is unexpected.

Situation is slightly different at the crossroads at which the green light DOES NOT end with blinking.

In these situations, when the amber turns on, the drivers usually apply the brakes sharper, which could, factually, be a result of, not only absence of the blinking green light, but also,

in some cases, a result of too short duration of the amber, in comparison to the approaching speed.

When the green light ends without blinking, it seems that diversity of the drivers behavior is more expressive, obviously as a result of present and expressed "zone of dilemma". When the amber turns on, a certain number of drivers that found themselves in the zone of dilemma, decide to apply brakes - mainly sharply, and the others continue driving or speeding up, entering the crossroads when the amber is about to end that is, at the beginning of the red light period.

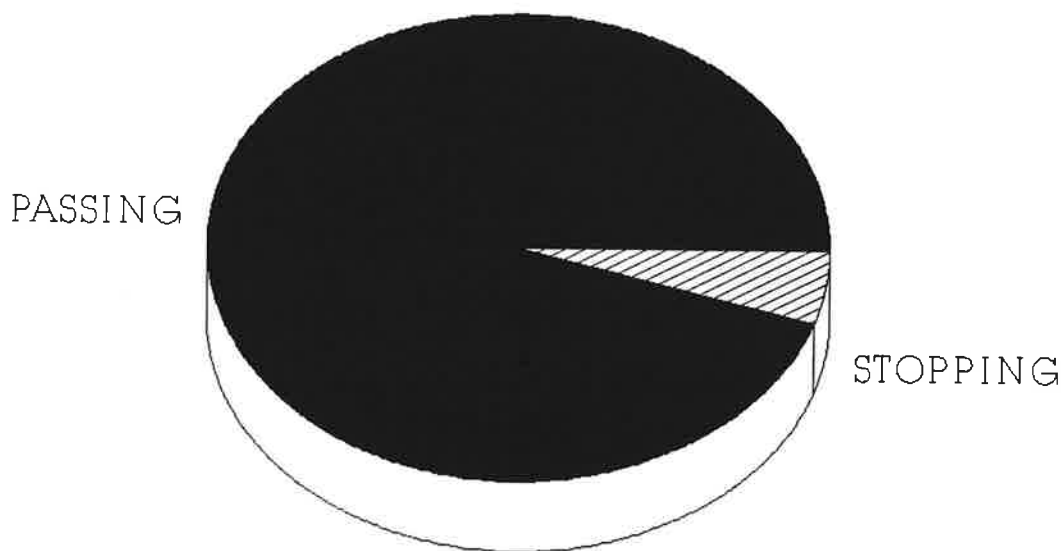
This, of course, can be very dangerous, although it appears that speeding up and passing through is less dangerous in such a situation, than a sharp braking.

4. Conclusion

Conclusion, imposed by the above presentation and comparisons, could be attributed to the following:

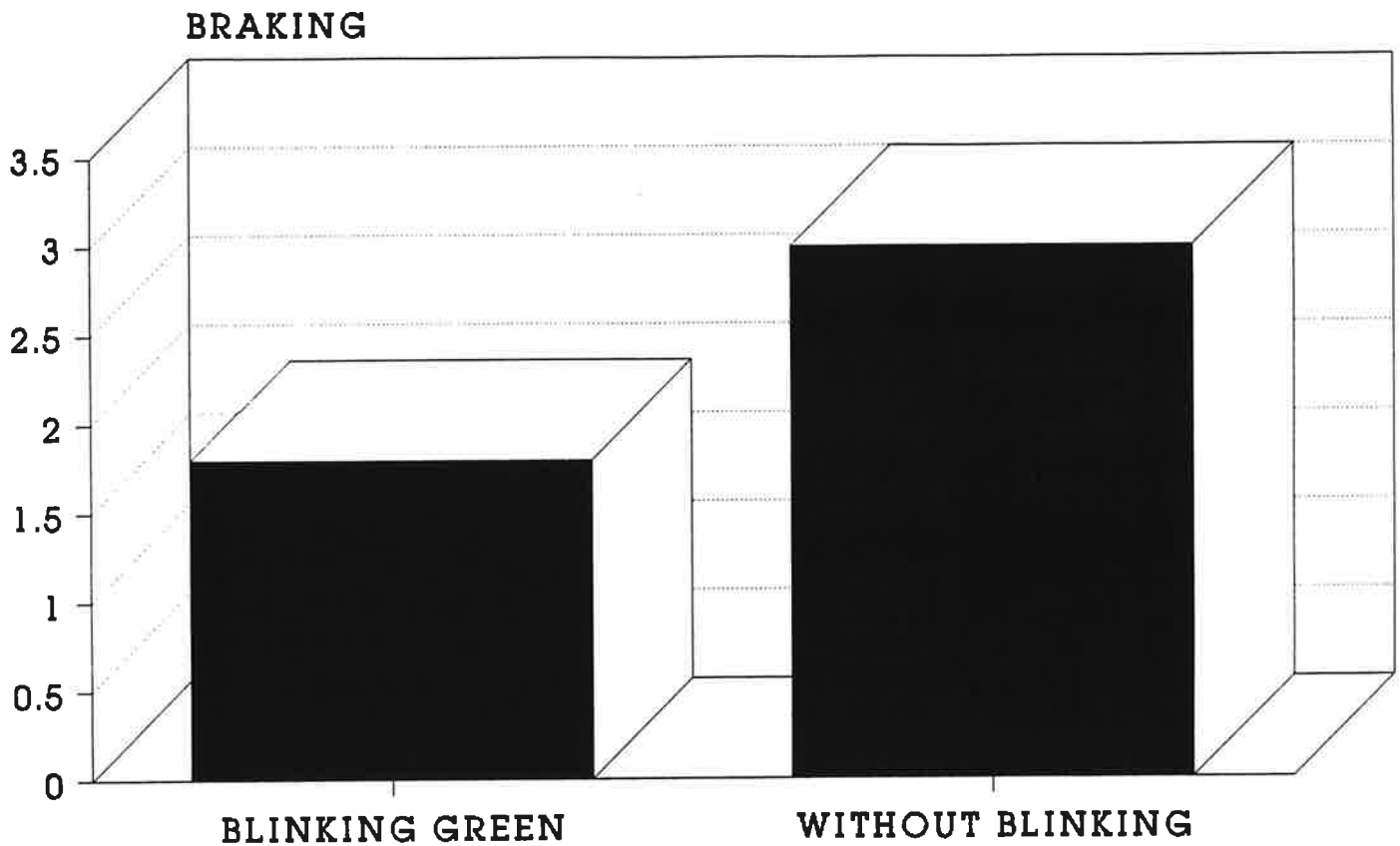
1. Appearance of the blinking green light at the end of the green phase almost does not have any influence on changes in the drivers behavior:

Figure 2: *Blinking Start (%), Estimate*



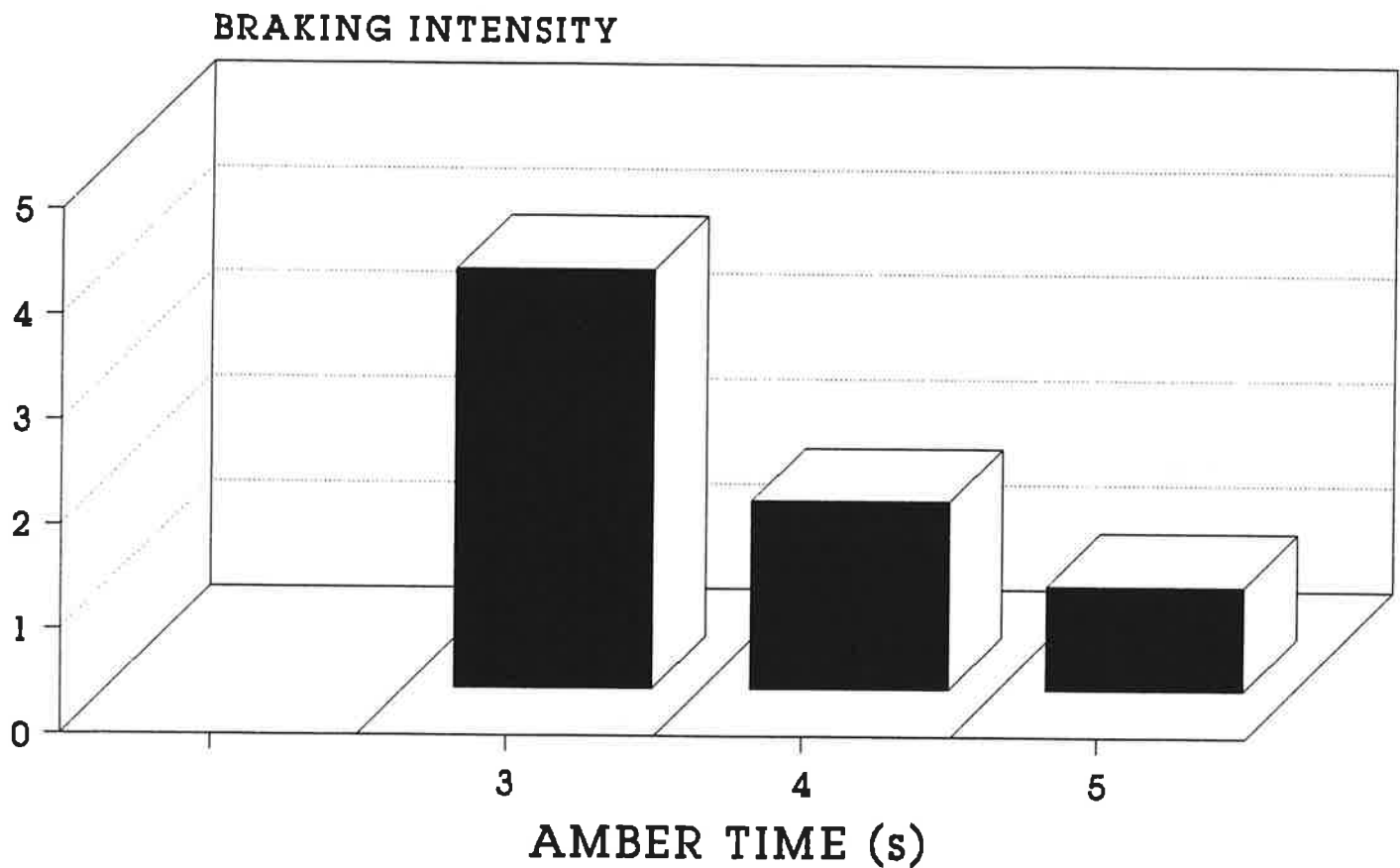
2. When the green traffic light, before it turns to the amber, ends **WITHOUT** blinking, stopping of vehicles is generally sharper - with more intense braking - than in the case when the green light ends **WITH** blinking. In other words, it could be asserted that a consequence of the blinking green light is more moderate stopping in front of the crossroads;

Figure 3: Braking Intensity at intersection, Estimate



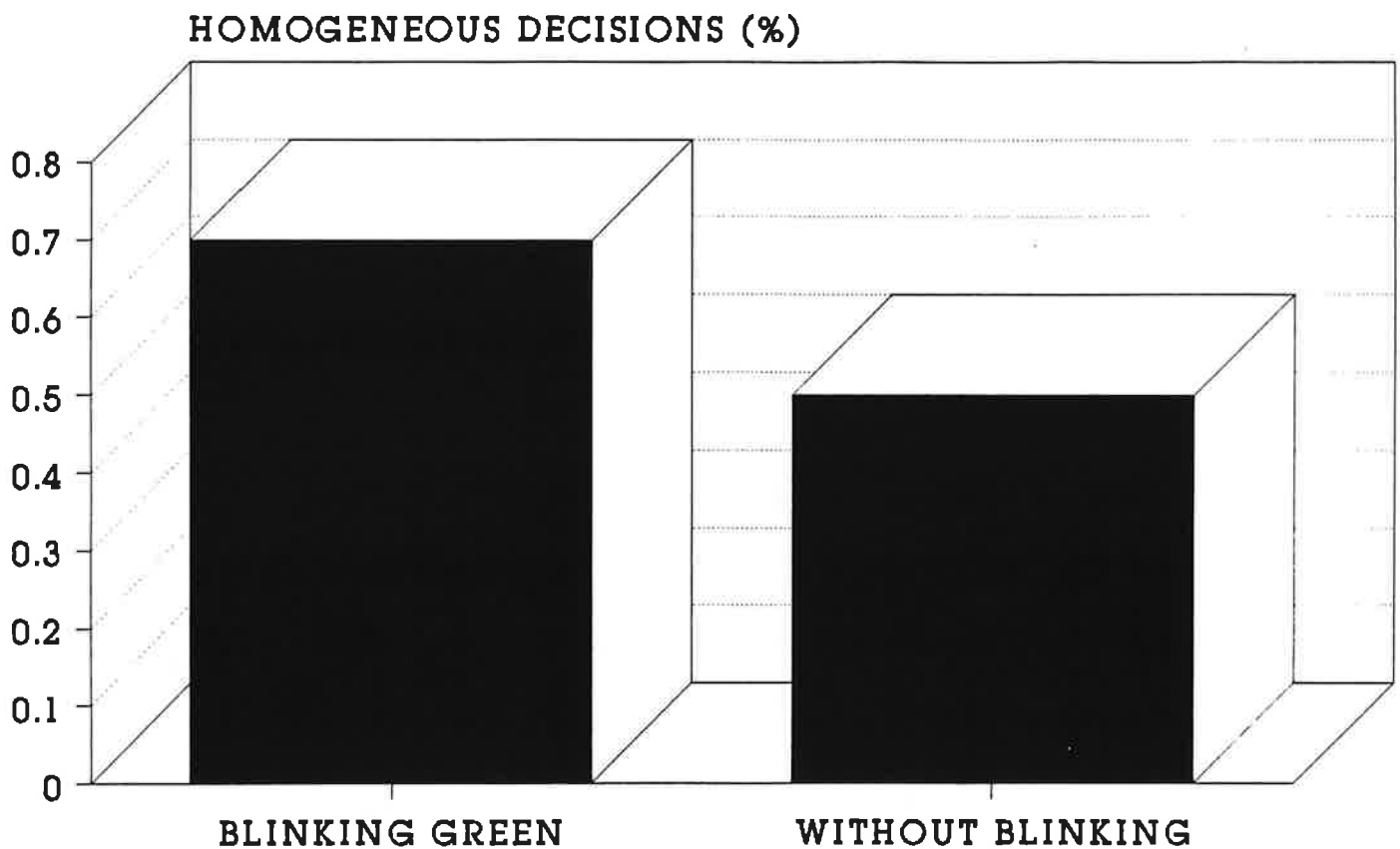
3. Duration of the amber influences the intensity of braking. When the amber, in relation to the approaching speeds of the vehicles, lasts shortly, that is, too shortly, then the intensity of braking becomes too high, which is not a good prerequisite for the traffic safety at the crossroads in any case.

Figure 4: *Amber time and braking intensity, Estimate*



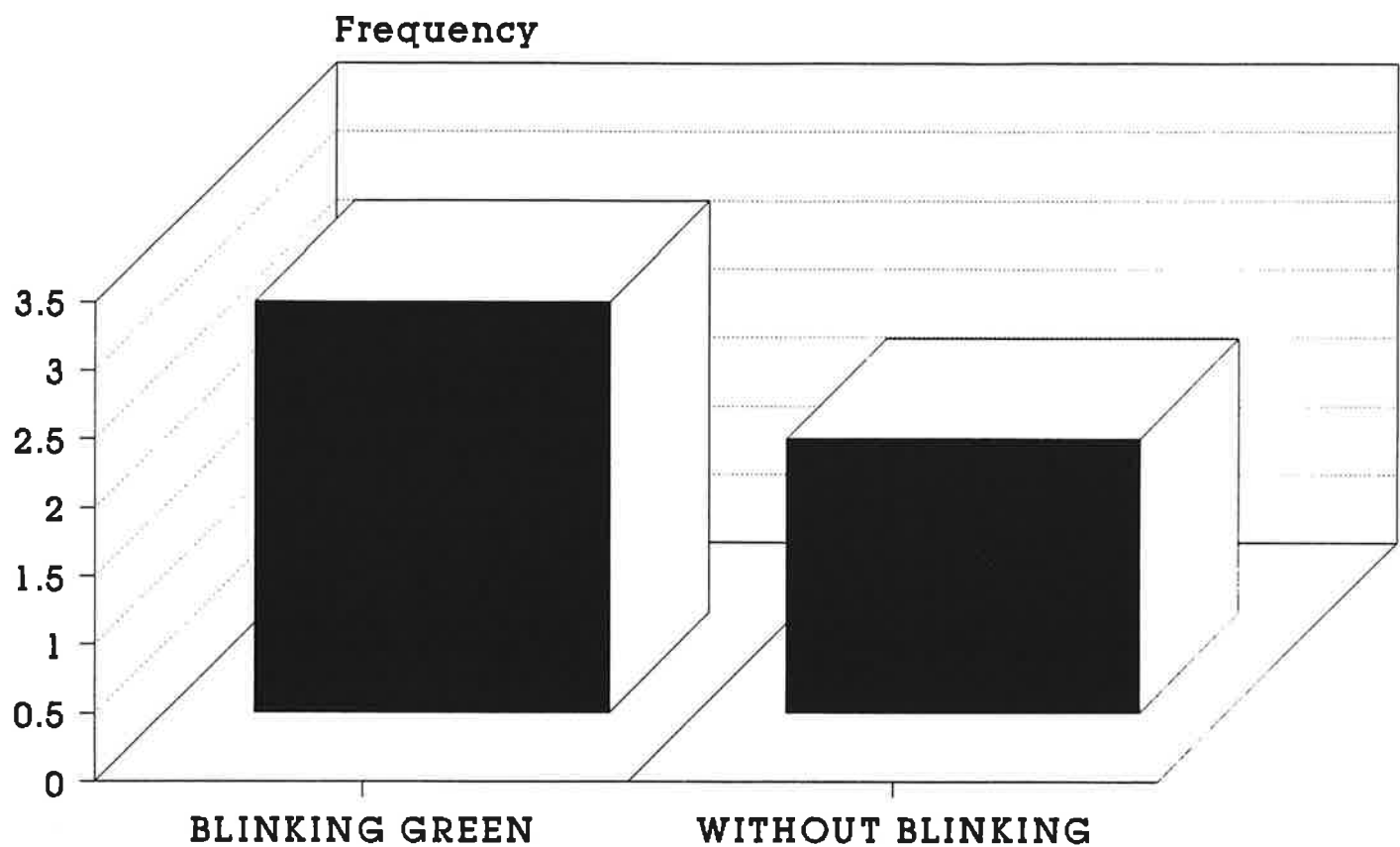
4. When the green traffic light, before it turns into the amber, ends WITHOUT blinking, it seems that non-homogeneity of the drivers reactions at the appearance of the amber is larger, that is, their behavior is more diverse. Namely, about 50% of the drivers, who at that moment found themselves in the “zone of dilemma”, continue driving, and about 50% of them start braking.

Figure 5: Decision homogeneity in „Indecision-Zone“, Estimate



5. When the green traffic light ends with blinking, it appears that drivers more frequently enter the crossroads on the red light.

Figure 6: Green phase and crossing against red, Estimate



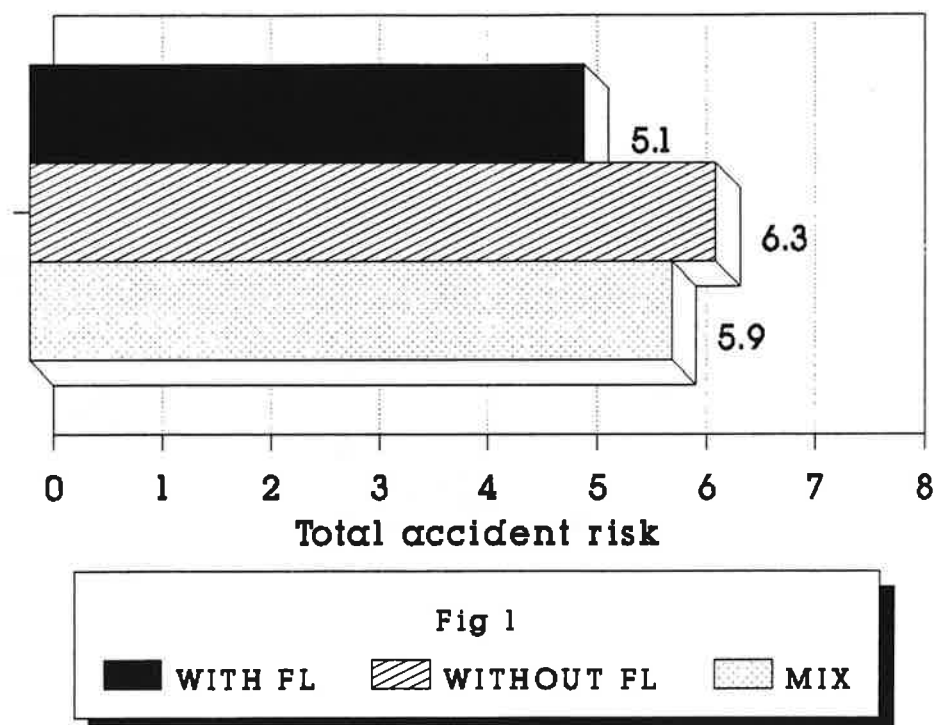
Could this conclusion contribute to the explanation and better understanding of recently obtained results from the statistic analysis of risks of the traffic accidents at the semaphored crossroads, with and without blinking green light before it turns into the amber?

Briefly, we obtained the following findings:

1. Blinking of the green traffic light influences a degree of the risk of the traffic accidents at the crossroads; When the green phase ends with blinking, the degree of the risk is LOWER, than when it ends without blinking and vice versa

Figure 7: Flashing Green influence on accident risk, Time Period: 1993-1995

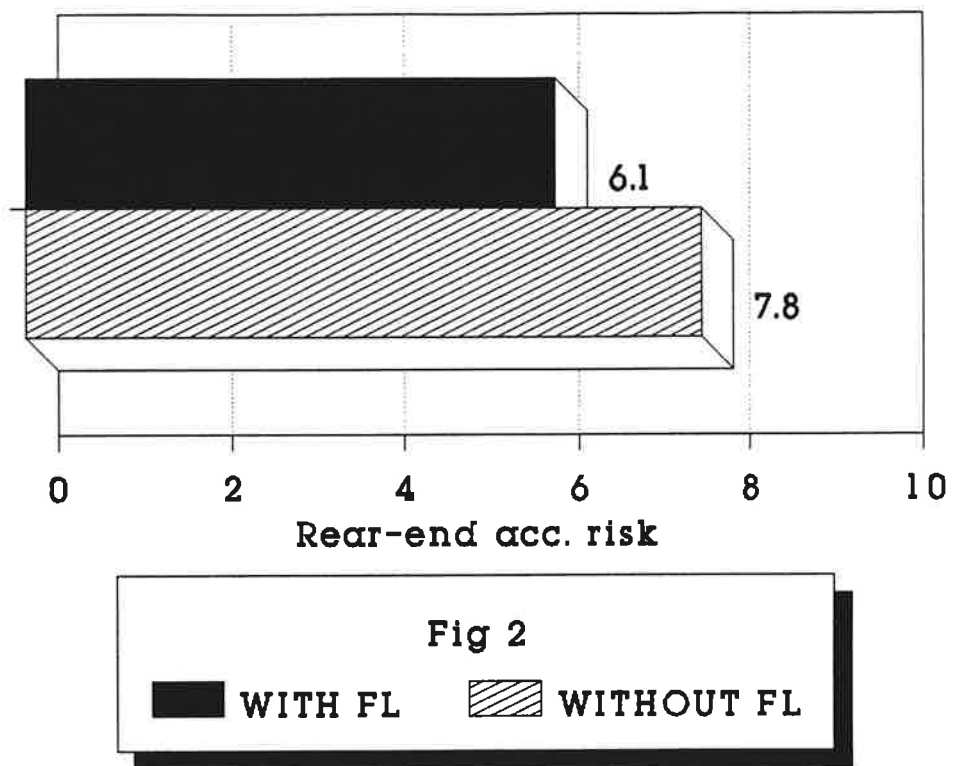
Green-phase end



2. Blinking of the green traffic light significantly influences a degree of risk for the rear-end collisions accidents; When the green phase ends with blinking, the risk of the rear collisions is LOWER, than when it ends without any blinking;

Figure 8: *Flashing Green influence on rear-end collisions, Time Period: 1995*

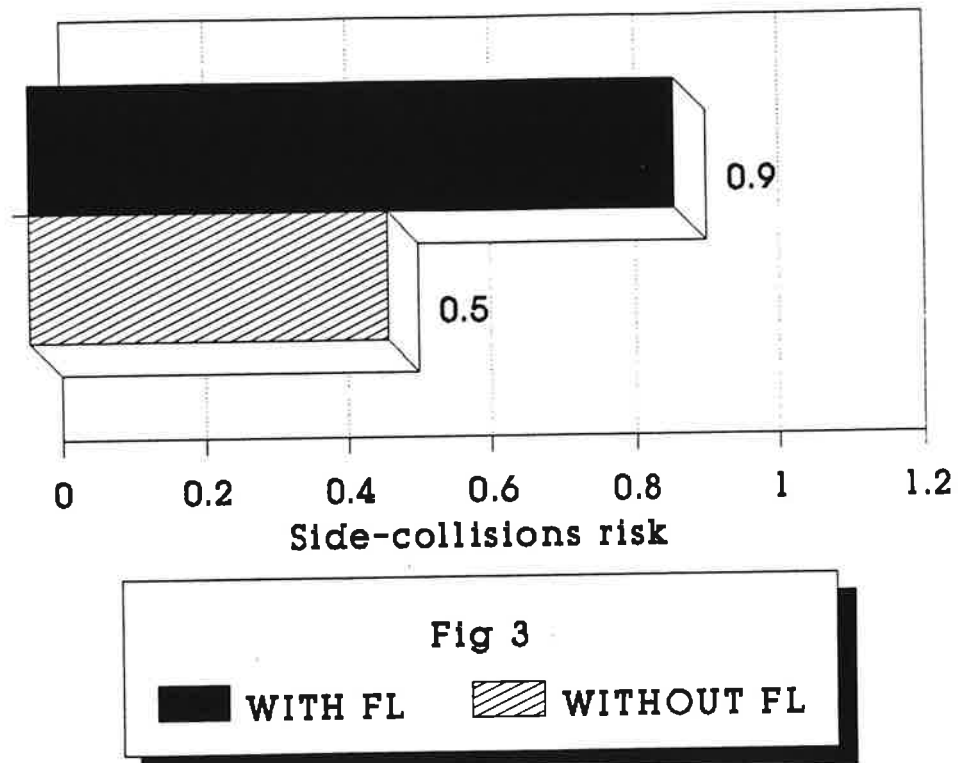
Green-phase end



3. Blinking of the green traffic light does NOT significantly affect the degree of the side collisions risk at the crossroads, although there are certain tendencies which could be observed in that sense; Namely, in case when the green light ends with blinking, a proportion of the side collisions is LARGER than when it ends without any blinking;

Figure 9: *Flashing Green influence on side-collisions, Time Period: 1995*

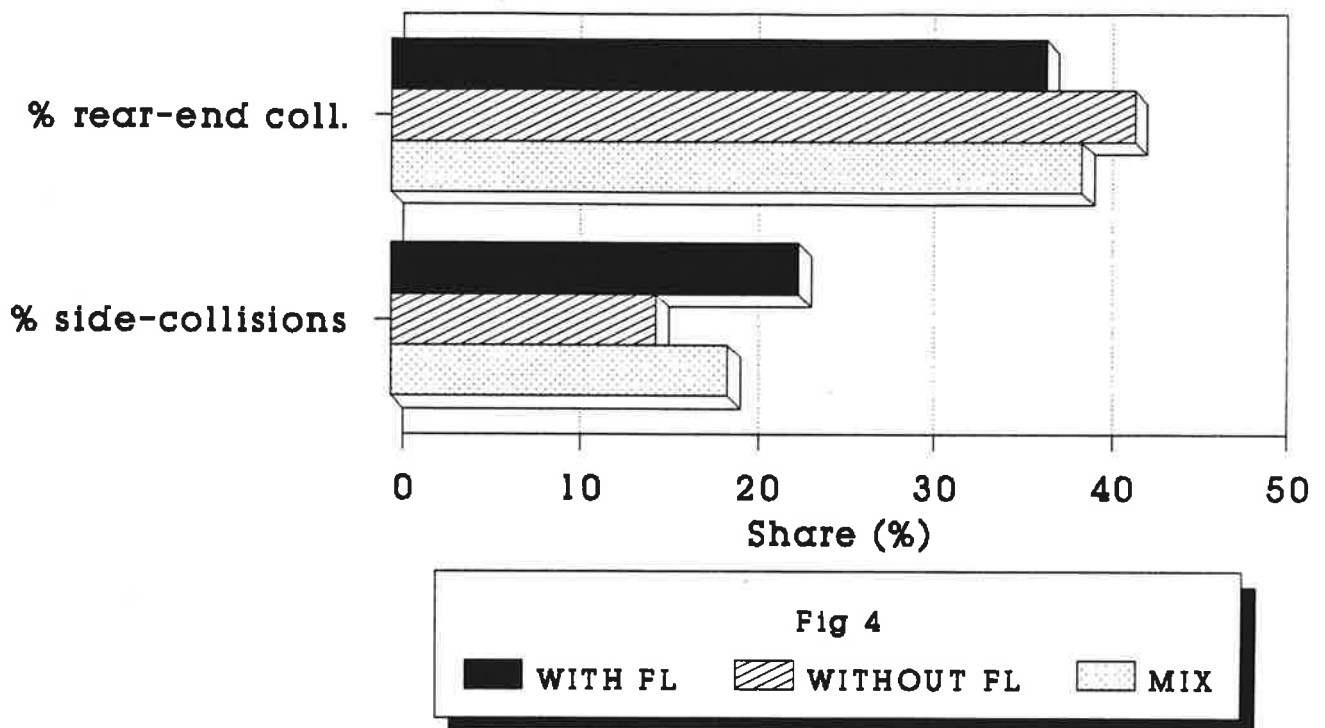
Green-phase end



4. Blinking of the green traffic influences the structure of the traffic accidents at the crossroads in a specific way; In case the green phase ends in such a way, a share of the side collision accidents is **HIGHER** than in cases in which the green phase ends without any blinking;

Figure 10: Flashing Green and accidents structure, Time Period: 1993-1995

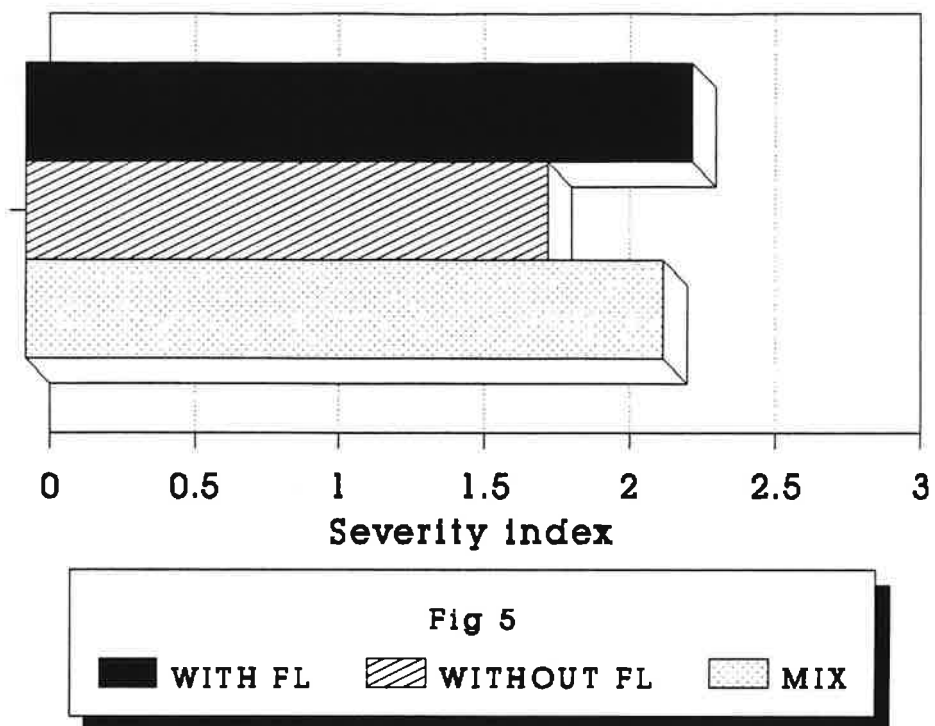
Green-phase end



5. Blinking of the green traffic light **INCREASES** the factor of severity of the traffic accidents, that is, it results into more serious consequences of the accidents;

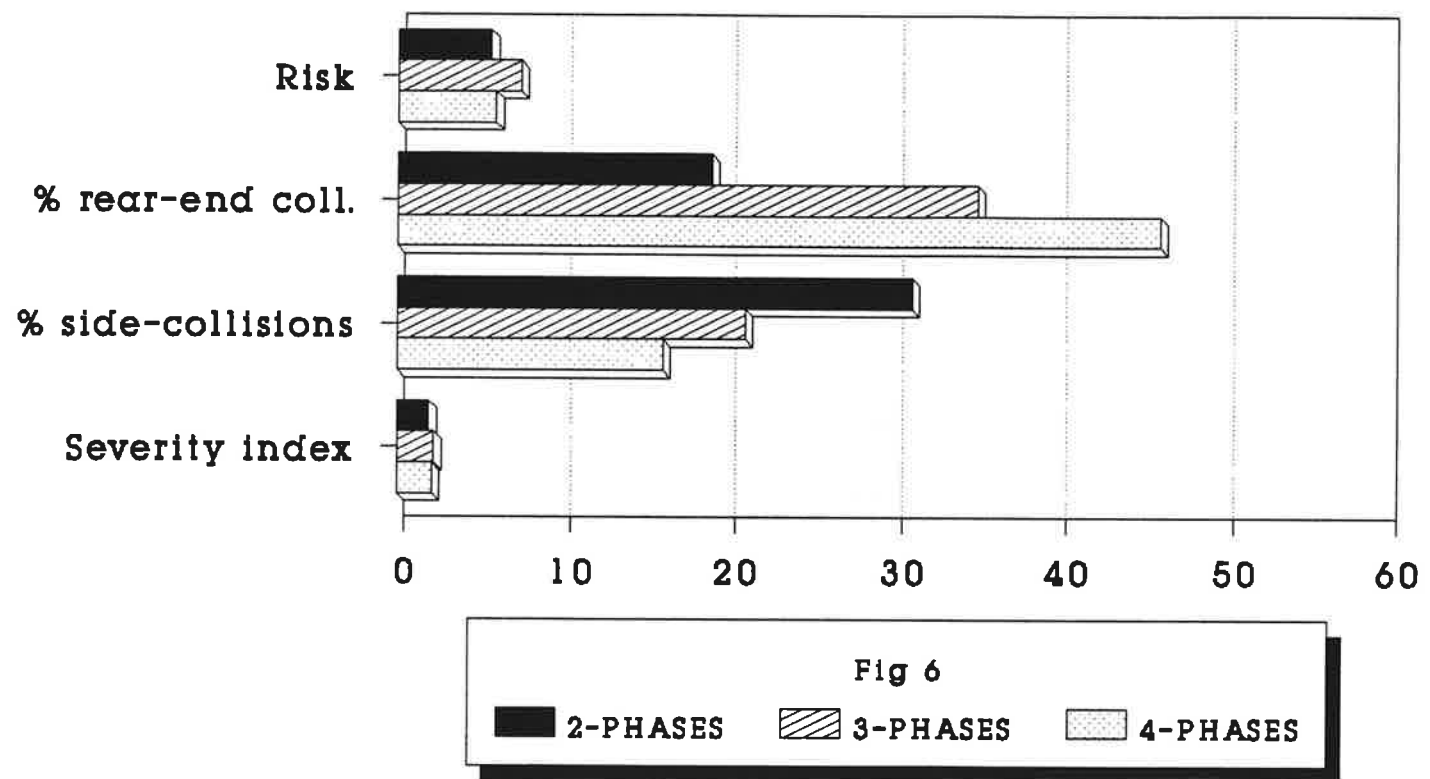
Figure 11: Flashing Green influence on accidents' severity, Time Period: 1993-1995

Green-phase end



6. Number of phases within the traffic light cycle does NOT influence the degree of risk of accidents at the crossroads, but it AFFECTS their structure; The larger the number of phases is, the higher is the portion of the rear-end collisions in the total number of accidents, and the number of the side collisions is smaller, and vice versa; Number of phases within the cycle does NOT influence the factor of severity in the accidents;

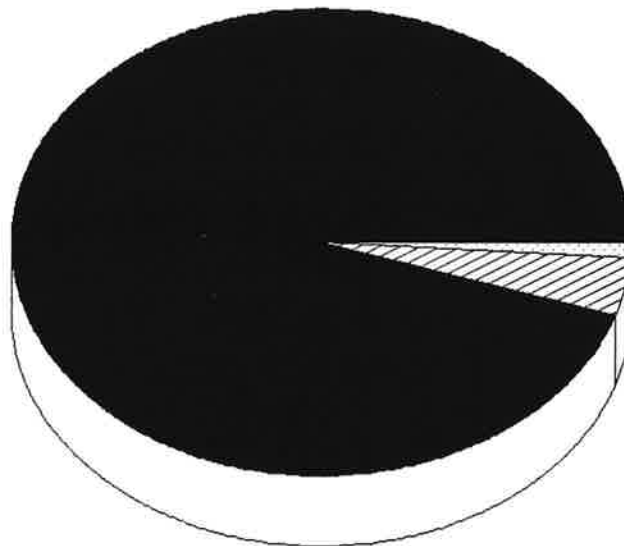
Figure 12: Signal Program (Phase), Time Period: 1993-1995



Drivers mainly have a clear attitude toward the ending of the green traffic light, but in most cases their attitude is as follows: "In my opinion, the blinking of the green light at the end of the phase is useful and necessary, because it provides me more time to make a proper decision."

Figure 13: Drivers survey attitudes (%)

FLASHING USEFUL 95



FLASHING DANGEROUS

FLASHING USELESS 4

When the findings obtained from previous analysis of risk, and the results obtained from the previous comparisons, are considered together, it appears that a role of the blinking green light could be briefly explained as follows:

- ◆ Blinking of the green light at the end of the phase, before it turns into the amber, results into more homogeneous way of reaction of the drivers to the amber, and also toward stopping of the vehicle with a lower intensity of braking, but it at the same time results into more frequent entering the crossroads on the red light.
- ◆ This way of behavior of the drivers in case of the blinking green light could explain a lower risk of accidents involving the rear-end collisions and an increased share of the side collisions accidents within the traffic accidents structure, that is, a higher factor of severity of the traffic accidents in such cases;
- ◆ When the green phase ends without blinking, it results into a larger variety of the drivers behavior toward the amber, toward more intense braking when stopping the vehicle; (which is higher if the approaching speeds are higher, and the duration of the amber is shorter).

This way of the drivers behavior when the green light ends without blinking could explain a higher risk of the rear-end collisions at these crossroads.

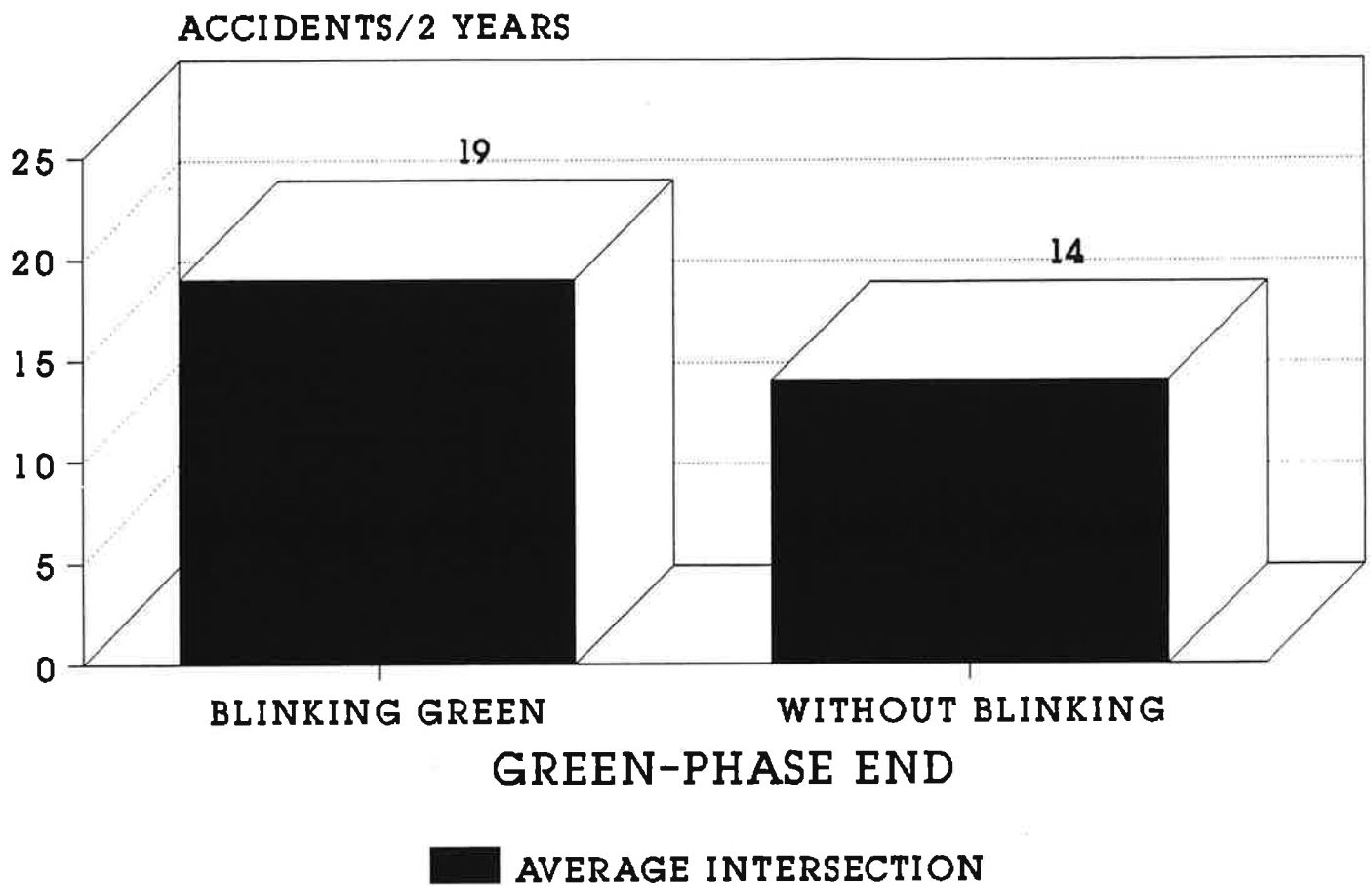
Some other, earlier and very famous researches, like those conducted by Israel, for example, obtained significantly different results.

The three-year traffic accidents analysis on a sample of 319 urban crossroads in Israel, found that a mean number of the rear-end collisions was higher at the crossroads equipped with the blinking green light, than at those equipped only with the amber. On the other side, they registered a slightly lower number of the side collisions at the crossroads equipped with the blinking green light. They found out in the conclusion that blinking of the green light increases a number of the rear-end collisions, and that virtually there were no other significant changes.

Significantly different results compared to ours, were obtained from the researches conducted by Becker (conducted also in Israel), which determined that 35% of the drivers, who found themselves in the zone of option at the moment when the green light starts blinking, make decision to pass through, and 65% of them make a decision to stop.

There is a possibility that some of these differences follows from different legal interpretations of certain terms, but also from different applications of the technical solutions as, for example, from different duration of the amber.

Figure 14: Israel Study, Hakkert, Mahalel



REFERENCES

GLEDEC M. (adopted 1986, revised 1992), Zagreb Master Plan

GLEDEC M., EVANS A. (1994), The Evaluation of Public Transport Safety Measures,
Public Transport International, 3-1994, pp 32-35,

GLEDEC M. (1995), Zagreb Statistical Yearbook

GLEDEC M. (1995), The Police Bulletin on the traffic safety in City of Zagreb