Risto KULMALA
Technical Research Centre of Finland
Espoo

DRIVER BEHAVIOUR AT URBAN JUNCTIONS WITH THE RIGHT-HAND RULE

Abstract

This paper is based on a study, where driver behaviour was observed at three right-hand rule junctions in Helsinki. The study was made in co-operation with the Central Organization for Traffic Safety on a commission from the Ministry of Communications. The purpose was to investigate how frequently risky behaviour occurs at junctions, and which factors affect it. We experimented with a method, where we observed the driver's observations, driving speeds, risk taking, and conflict situations. The data consisted of 2,399 vehicle drivers as passing through a junction.

Background

In urban areas, the accidents often occur at junctions. According to the statistics of traffic insurance companies, more than half of the accidents and their casualties on urban streets occur at junctions.

The driver's risk taking by driving too fast or utilizing too short safety margins has often been named as the main cause for junction accidents. Observational and judgmental errors also contribute to junction accidents in urban areas. The frequent environmental causes have been e.g. poor sight conditions in heavily built city centres or a "psychological right-of-way" opposite to the prevailing priority situation.

Study method and data base

We studied the drivers' observations and speeds at entering the junction, risk taking for the part of accepted gaps and safety margins, traffic violations, and conflict situations. The main hypotheses are presented in Figure 1.

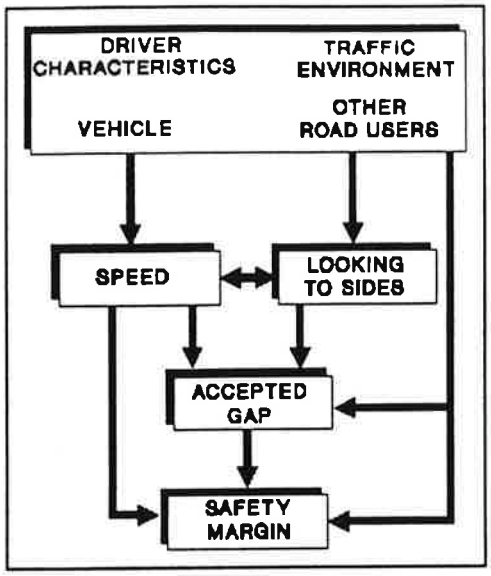

Figure 1. Factors affecting risky behaviour at urban junctions.

We tried to choose three right-hand rule junctions without signal control, but with many accidents. The traffic volumes should be high to enable us to gather many observations in a short period of time. In addition, the junctions should permit observations without attracting attention or disturbing the traffic. The following junctions were chosen on the basis of our own experiences, and the information from the Helsinki City Planning Department:

- Snellmaninkatu and Kirkkokatu
- Helsinginkatu and Kirstinkatu
- Fleminginkatu and Agricolankatu

Our observation consists of a driver's behaviour while he/she is passing through the junction. We decided to study vehicles entering the junction from one arm only. The arm was chosen on the basis of both the traffic volumes as well as our observational possibilities. We always chose the most wide street, and also the one with the tram line (Snellmaninkatu and Helsinginkatu). Thus we thought in advance that the arms studied had the so-called psychological right-of-way. The sight conditions were at all three junctions very poor especially to the right.

We only included in the data such vehicles, which could freely choose their speeds and actions when approaching the junction. This meant that there were no other vehicles approaching the junction from the same arm before the studied vehicle. Thus only single vehicles or platoon leaders were accepted in the data base.

The field studies were performed in good weather in working days during the periods of 11.00 — 12.00, 13.30 — 14.30 and 15.30 — 16.30. The data base consisted of 2,399 acceptable observations. 74 % of the vehicles were cars, and 15 % were vans. 89,1 % of the drivers were male. 40 % of the drivers were young, 47 % middle aged, and 13 % elderly. 27 % of the vehicles had passengers on the front seat, and 10 % on the back seat.

The average hourly flows for straight driving vehicles from the studied arm, and for

those coming from their right were:

	Straight	From right
Snellmaninkatu	190	370
Helsinginkatu	290	70
Fleminginkatu	190	60

24 % of the vehicles braked at entering the junction. This percentage does not include those that braked and stopped before entering the junction. The percentage braking was the following for the three junctions:

Snellmaninkatu	12,4 %
Helsinginkatu	31,7 %
Fleminginkatu	22,1 %

In Snellmaninkatu, one vehicle had to wait for 12 vehicles from the right before driving through the junction.The average waiting times were (including those with a waiting time of 0 seconds):

Snellmaninkatu	2,5 s
Helsinginkatu	0,9 s
Fleminginkatu	0,2 s

Driver's observation making

By observation making, we here mean that the driver turns his/her head and looks to the right and/or to the left. If all driving directions are included, 32 % of the drivers looked to the left, 80 % to the right, and 27 % to both directions. One fifth thus neglects to look right at a right-hand rule junction. In the following we concentrate on the straight driving vehicles from the arm studied, because the priority situation is clear, and there are enough observations (Table 1).

Table 1. The drivers' looking to the right - straight drivers only (N = 1,736).

Junction studied	Driver looked to the right	
	number	%
Snellmanink.	419	90
Helsingink.	394	67
Flemingink.	563	83

In Snellmaninkatu, the volume from the right was the largest. Thus it is not surprising that the percentage looking to the right was highest at this junction. The psychological right-of-way was most apparent on the straight and wide Helsinginkatu with the tram line and the highest speeds. The drivers were thus also less frequently prepared for giving way at this junction.

Driving speeds at entering the junction

The speeds were measured **just as the vehicle was entering the junction** i.e. on the pedestrian crossing before the junction. The mean speeds were:

Straight driving vehicles	25,7 km/h
Left turning vehicles	13,7 km/h
Right turning vehicles	21,3 km/h

The mean speeds of the straight driving vehicles were at the different junctions:

Snellmaninkatu	15,6 km/h
Helsinginkatu	32,7 km/h
Fleminginkatu	26,9 km/h

In Snellmaninkatu, the junction is entered with clearly lower speed than at other junctions. In Helsinginkatu, the speeds were slightly higher than in Fleminginkatu. Figure 2 presents the cumulative speed distributions of the various junctions.

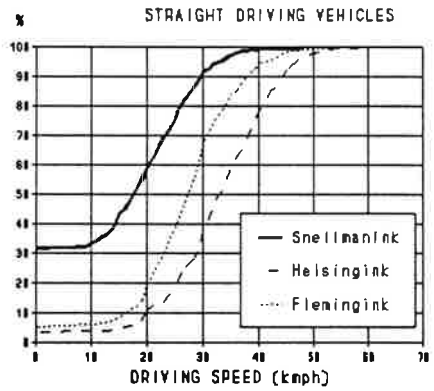

Figure 2. The cumulative speed distribution at the three junctions studied.

The speeds are lowest at the Snellmaninkatu junction. This is probably due to the large volumes from the right, which most of the drivers are certainly aware of. At the Helsinginkatu junction, the speeds are highest because of the by far broader street emphasizing the psychological right-of-way. The psychological right-of-way seems to be less evident in Snellmaninkatu, where speeds are especially low in situations, where a vehicle is approaching the junction from the right at the same time.

The mean speeds according to the drivers' looking to the right are shown in Table 2.

Table 2. Mean speed as a function of whether the driver looked to the right (km/h).

JUNCTION	LOOKED TO RIGHT		DIFFER-ENCE
	NO	YES	
Snellmaninkatu	25,9	15,6	10,3
Helsinginkatu	37,3	30,3	7,0
Fleminginkatu	32,8	25,7	7,1

Drivers looking to the right before entering the junction do so with a lower speed than other drivers. These drivers are evidently generally more cautious than other drivers. The difference is especially clear, when another vehicle is also coming from the right. This we interpreted as an evidence of the psychological right-of-way i.e. at least some of the drivers not looking to the right really think that they have the priority.

It is interesting that the speeds of such drivers, which do not look to the right, are at their lowest, when a vehicle is coming from the right. This means that some drivers look sideways at urban junctions without moving their heads.

The mean speeds did not vary according to vehicle type, driver age, or other activities performed by the driver while driving (eating, talking to phone etc.). The sex of the driver and the existence of passengers, however, affected speeds.

Women enter the junction with a (on average 3 - 4 km/h) lower speed than men. Women have usually more cautious driving habits than men. The results also indicate that men look sideways at junctions without moving their head more often than women.

Drivers, who have passengers with them, enter the junction at a circa 1.5 km/h lower speed than drivers driving alone.

Risk taking

Risk taking at junctions is here studied mainly for the part of accepted gaps and safety margins. Only straight driving vehicles are studied. These should give way to all vehicles approaching the junction from the right.

As a driver enters a junction at approximately the same time as another vehicle, which has the priority, he has to decide whether he drives through the junction before the other or yields. The other vehicle's distance naturally affects this decision to a large extent. This distance is called **time gap**, if it is measured in time.

The gap, during which the vehicle drives through the junction, is called an **accepted gap**. If the driver does not use a gap, it is called a **rejected gap**. Thus each vehicle has

one accepted gap, but the number of rejected gaps can vary. In this study the number of rejected gaps was between 0 and 12, and the zero class was the most frequent. Risk taking generally increases as the length of the accepted gap decreases.

The **safety margin** is the part of the accepted gap which remains between vehicles as they pass through the crossing/meeting point of their courses. Thus the safety margin is always shorter than the accepted gap. Also for safety margins low values correspond to increasing risk taking.

Traffic violations can also be regarded as a form of risk taking, although their risky features can be quite ambiguous. The most severe forms of risk taking are naturally **conflicts and accidents**.

Accepted gaps

Figure 3 shows the accepted gaps' portion of all gaps of certain length. The gaps are classified in intervals of one second.

The drivers in Helsinginkatu and Fleminginkatu accept very short gaps, as at least 70 % of gaps in the class of 2 seconds (1,5—2,5) are accepted by them. In Snellmaninkatu, drivers accept longer gaps, which is partly due to the great number of drivers having to stop at the junction. It takes a longer time for a stopped vehicle to pass through the junction, and thus also a longer gap. The extra gap time required by stopped vehicles was ca. 2 seconds.

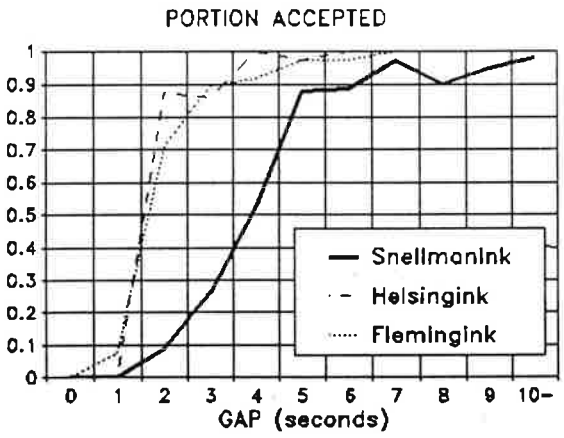

Figure 3. The portion of accepted gaps of all gaps with certain length at the study junctions.

Drivers that look to the right seldom accept short gaps. Drivers that do <u>not</u> look to the right accept all gaps longer than 2.5 seconds at the Helsinginkatu and Fleminginkatu junctions, and all gaps longer than 5.5 seconds at the Snellmaninkatu junction.

The accepted gaps are the shorter the higher speed is used in entering the junction. The gap is on average 0.11 seconds shorter for every 10 km/h's speed increase. The accepted gaps are on the other hand the longer the more vehicles are entering the junction from the right-hand arm during that hour. Every 100 vehicles' increase in

hourly volume causes an average increase of 0.14 seconds in the accepted gaps.

We regarded especially interesting very short accepted gaps, and the situations where these occur. All accepted gaps of less than 2.5 seconds were classified as "risky". As the situations, where no vehicles are approaching from the right at the time of driving through the junction, were of little interest here, we rejected all vehicles with an accepted gap of longer than 8 seconds from this part. All gaps of more length than 8 seconds were always accepted in this study anyhow.

The speed at which the vehicle enters the junction was the most important factor explaining the occurrence of short accepted gaps (see Figure 4).

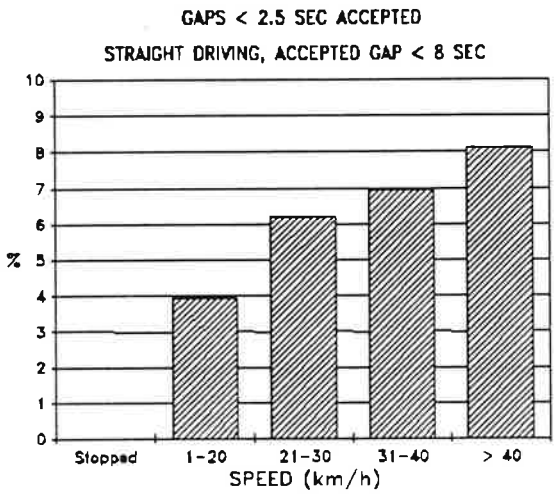

Figure 4. The percentage of 2.5 or shorter gaps of all gaps shorter than 8 seconds accepted by straight driving drivers.

The probability of accepting a short gap increases with increasing speed. No driver that has stopped before entering the junction accepts a short gap, but ca. 8 % of the drivers having a speed of more then 40 km/h accepts a shorter than 2.5 second gap.

Safety margins

The safety margins were affected by the junction, speed, looking to the right, and the sex of the driver.

In Snellmaninkatu, the safety margins were on average ca. 0.6 seconds longer than in Helsinginkatu. In Fleminginkatu, the safety margins were shortest, on average 0.5 seconds less than in Helsinginkatu. The speed increase of 10 km/h causes an average increase of 0.14 seconds in the safety margins.

The women's safety margins were on average 0,2 seconds longer than men's. The drivers looking to the right had on average 0.1 seconds longer safety margins than those neglecting to look to the right by moving their head.

Traffic violations

At the Snellmaninkatu and Fleminginkatu junctions two thirds of the violations were situations, where a pedestrian crossed a street outside a marked crossing. In Helsinginkatu, where the street is wider, such violations were rare.

The number of incorrect driving orders (the vehicle with priority has to give way) was by far the highest in Helsinginkatu, and lowest in Fleminginkatu.

Although the number of traffic violations was quite low in the data base, we tried to study whether the drivers committing such a violation would differ from the other drivers. This analysis gave the following results:

- The violators' safety margins were more frequently risky i.e. less than 1.5 sec.
- Taxi drivers commit violations more frequently than other drivers
- The drivers that stop at the junction, and also those entering the junction at a speed of more than 40 km/h commit violations more frequently than the other drivers.
- Male drivers commit violations more often than female drivers.
- Drives neglecting to look right are more often committing violations than those looking to the right.

Conflicts and accidents

We applied our standard Traffic Conflict Technique for this study. Table 3 lists the number of hazardous situations (conflicts and potential conflict situations) per hour at the junctions studied. The corresponding numbers of accidents per five years are shown in Table 4.

The hourly number of hazardous situations was highest at the Snellmaninkatu, and lowest at the Fleminginkatu junction. The accident numbers from a period of five years vary from junction to junction almost exactly in the same ratio as the number of hazardous situations. The number of incidents involving unprotected road users was low.

Table 3. The number of hazardous situations at the study junctions. (MVEH = motor vehicle, UNPRO = unprotected road user i.e. pedestrian or bicyclist)

JUNCTION	MVEH-MVEH	MVEH-UNPRO	TOTAL	TIME (h)	SIT./h
Snellmaninkatu	9	0	9	6	1,5
Helsinginkatu	11	0	11	9	1,2
Fleminginkatu	2	2	4	10	0,4

Table 4. The number of police-reported traffic accidents in 1983 - 1987 at the study junctions.

JUNCTION	MVEH-MVEH	MVEH-UNPRO	TOTAL	TIME (a)
Snellmaninkatu	40	3	43	5
Helsinginkatu	30	3	33	5
Fleminginkatu	7	2	9	5

Most of the accidents and hazardous situations were such, where the participants drove to the junctions from crossing streets (priority situations).

Summary of results

Most of the drivers behave in a safe manner while driving through the junction: 80 % looked to the right by turning their head, only a few used a speed higher than the 50 km/h speed limit, less than 2 % of the drivers accepted a gap of less than 2.5 seconds, and less than 5 % of the drivers had a safety margin of less than 1.5 seconds.

Although the majority drives according to the expectations and regulations, the number of drivers neglecting to look to the right is alarmingly high. One out of every five drivers does not turn his head to look to the right at entering a right-hand rule junction. If only a vehicle should come to the junction from the right at the same time, the risk of a collision would be high.

On the other hand, a speed of 50 km/h is much too high at a junction with poor sight conditions, though the regional speed limit is such. At the studied junctions a safe speed would be ca. 20 - 30 km/h. Most of the drivers (63 - 98 %) entered the junction at a speed of 30 km/h or less.

The study indicated that many of the drivers observe traffic from the crossing streets without turning their heads. It is, however, debatable, whether such habits can be regarded as safe traffic behaviour or not.

The behaviour of the drivers differed significantly in the various junctions. In Helsinginkatu, the broadest street in the study, the drivers often (33 %) neglected to look to the right, entered the junction at a high speed, accepted short gaps, and committed violations most frequently. In addition, the number of short safety margins and hazardous situations were higher than what would be expected on the basis of the traffic volumes. We regarded this as a result of the psychological right-of-way in the 8broad Helsinginkatu. Thus all of the drivers do not beware of the vehicles coming from the narrow Kirstinkatu. This was evident from the high number of incorrect driving orders i.e. situations, where the driver with the priority has to give way to a vehicle supposed to yield. The psychological right-of-way is amplified by the traffic volumes (more than 5:1), and the tram line and refuges in Helsinginkatu.

In Snellmaninkatu, the psychological right-of-way was not very obvious as 10 % did not look to the right, speeds were lowest in this study, and the accepted gaps as well as safety margins were longer than at the other junctions. The high number of traffic violations and especially of incorrect driving orders indicate some priority problems. The high number of hazardous situations and accidents are mainly resulting from the higher traffic volumes, but also from the poor sight conditions. This is why a mirror has been put up at the junction to enable the early observation of approaching vehicles from the crossing street.

The psychological right-of-way at the Fleminginkatu junction is somewhere in between of the other two junctions, but it is much safer according to traffic violations, hazardous situations, and traffic accidents. This is mainly due to the low volumes in Agricolankatu.

Risky behaviour

We assumed in starting the study that risk taking in approaching urban junctions occurs as neglecting to observe traffic from the crossing streets and using high speeds, and at the junction itself as accepting short gaps. This then would result in short safety margins, traffic violations, and hazardous situations.

The study confirmed most of our assumptions. Traffic violations and short accepted gaps are more frequent for drivers that enter the junction at a high speed and neglect to turn their head in order to look to the right. The neglect of looking to the right was in strong correlation with high speeds.

The sex of the driver correlated with risky behaviour. Female drivers enter the junction at lower speeds, and also stop more frequently. The difference was especially notable, when another vehicle was approaching the junction from the right. Female drivers were more seldom involved in short safety margins and traffic violations. Male drivers seemed to observe traffic in the crossing streets more frequently without turning their heads, probably due to more driving experience.

Measures

If one of the streets at a right-hand-rule junction has the psychological right-of-way, it is best for traffic safety to mark the priority officially with the yield signs.

As the yield signs along urban streets can not be restricted to some junctions only, the recommendation above would lead to signs along all main and collector streets. This is the practice in most European countries. The sign simplifies the situation, and at junctions, where it confirms the psychological right-of-way, it has also reduced accidents involving vehicles from crossing streets.

The system has a problem in increasing the speeds along the priority street, and thus making it more difficult and hazardous for pedestrians and cyclists to cross the street. The situation must be reviewed for all road user groups before applying the yield signs.

Traffic planners should in all cases beware of planning and building junctions, where there is a possibility of a psychological right-of-way opposing the prevailing priority situation.

References

Kulmala, R., Auranen, T. & Heinonen, M. Kuljettajakäyttäytyminen kolmessa tasa-arvoisessa taajamaliittymissä (Driver behaviour at three urban junctions). Valtion teknillinen tutkimuskeskus, tiedotteita 1168. Espoo 1990. 52 pp. + app. 8 pp.