Development of a traffic conflicts technique for different environments
A comparative study of pedestrian conflicts in Sweden and Jordan

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Keywords:
Traffic safety, traffic conflict technique, pedestrian conflict, relevant road-user, threshold, severity index, conflict sub-grouping, time to accidents, conflict speed, TA-speed graphs, accident to conflict conversion factors, accident prediction, signalised junctions, non-signalised junctions, perception of conflicts.

Abstract:
This study is aimed at improving the current Swedish Traffic conflicts Technique [TCT] in relation to vehicle-pedestrian conflicts. The present definition of conflict severity appears to produce less severe conflicts than they might be, particularly if the relevant road user (RRU) is the pedestrian. Another aim is to apply the Swedish TCT in Jordan as a method for evaluating safety conditions at junctions. The difference in conflict perception in the two countries is explored throughout this thesis.

The study was based on collecting data [accident, conflict, and traffic volume] from selected junctions with and without signal control in urban areas (20 junctions in Sweden and 22 junctions in Jordan). Alternative definitions of traffic conflicts and RRU were validated against the present definition of serious conflicts.

The results indicated that the present definition of serious conflicts could be improved. The most valid definition of conflicts for non-signalised or signalised junctions or both junction types together was obtained by shifting the present threshold to the more severe direction of the time to accident-speed graph by 0.25 seconds. The present definition of RRU (road-user who acted evasively and was subjected to the least severe situation) produced the most valid definition for non-signalised junctions. The high definition of RRU (the road-user who in the situation produced the highest severity, i.e. the driver) produced the most valid definition for signalised junctions. Sub-groups of conflicts were formed according to the present definition of conflicts by excluding conflicts that involved RRU under the high definition who is driving at a speed less than 20km/h. They produced accident predictions as those produced by the most valid definition of conflicts, particularly for non-signalised junctions. The results indicated that the most valid definitions in Jordan were not the most valid definitions in Sweden. Some conflict definitions, however, have high validity for non-signalised junctions in both countries. The technique must take into account the local conditions in order to be applicable in other countries. According to this study, a minimum requirement is to establish local conversion factors between accidents and conflicts, if the technique is to be applied for accident prediction purposes. Finally, the road-user perception of conflicts is different in the two countries.
Acknowledgement

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Lund, September 22, 2000
Lina Shbeeb
Summary

The present Swedish Traffic Conflicts Technique (TCT)

The basic concept in the present Swedish TCT is the assumption that nobody would like to be involved in a serious conflict voluntarily. Conflicts are envisaged to describe events that are characterised by a breakdown in the road-users’ interactions in traffic. To put the technique into practice two concepts were introduced. First, defining a threshold that differentiates serious from non-serious conflicts. Second, defining the road-user who is in a situation that determines the severity of the conflict and often referred to as the relevant road-user (RRU). Both concepts were used to define the severity of conflicts. The threshold was first introduced by considering a time-based scale, where the time to accident (TA-value) was only adopted to define the severity. TA-value is the time remaining until the two road-users would have collided had they continued with unchanged speeds and directions. This is measured when one of the involved road-users starts an evasive action. Later, the definition was modified to be speed and time dependent. A threshold that differentiates serious conflicts from other situations was based on the process validity concept that was introduced by Hydén (1987). The valid threshold was based on relating the TA-value of the relevant road-user to the conflicting speed. The relevant road-user was defined as the road-user that took evasive action and whose combined conflicting speed and time remaining to accident produced the least severe conflict. Conflicts were considered serious if the combined speed and time to accident value of the relevant road-users was above the threshold that intersects the X-axis of TA-speed graph at 0.5 seconds.

A number of problems associated with the present Swedish TCT in relation to pedestrian conflicts were identified:

- The present definition of conflict severity appears to produce less severe conflicts than they might be if the relevant road-user is the pedestrian.

- The number of variables that were considered during investigating the relationship between conflicts and accidents were limited due to the current data collection procedure. For example, additional information describing the dynamic properties of the situations is not collected in the present Swedish TCT.

- The present Swedish TCT has been applied in a number of countries mainly for diagnostic or evaluation purposes, but not as an accident predictive tool. In order to consider the use of the Swedish TCT as a predictive tool in any other country it is required to be validated under the local conditions.

Study objectives:

This study was aimed at improving the present Swedish TCT in relation to vehicle-pedestrian conflicts. The intended improvements in the Swedish TCT were aimed at eliminating as far as possible the perceived imperfections.
Equally important was the application of the Swedish TCT in Jordan as a method for evaluating safety conditions at urban junctions. The accident problem in Jordan is more serious than in Sweden as due to road-user’s behaviour, road infrastructure development, and the legislation and their enforcement.

The influence of the traffic environment on the road-users’ perception of conflicts in the two countries was also investigated. This is expected to provide an insight into the safety problem in both countries.

**Tested Hypotheses**

To achieve the conceivable aims the following hypotheses were formulated.

**Hypothesis 1:** The Swedish traffic conflicts technique can be improved in relation to pedestrian conflicts.

**Hypothesis 2:** The improved Swedish traffic conflicts technique can also be applied in Jordan.

**Hypothesis 3:** Conflict characteristics and their perception are different in the two countries.

**Study method**

Two methods were employed in this study. The observational method was used to collect data on conflicts and road-user behaviour. The second method was the verbal technique used for interviewing some of the pedestrians involved in conflicts and rating the severity of the selected conflicts by three groups of observers.

For the purpose of verifying the hypotheses, particularly the first two hypotheses, two identical studies were carried out, in Sweden and in Jordan. Twenty junctions in Sweden and twenty-two junctions in Jordan were selected, half of them were signalised and the others were non-signalised. They were in urban areas with a speed limit of 50km/h in Sweden and a speed limit that does not exceed 60km/h in Jordan. Traffic volumes at the selected sites vary from low traffic volumes at some non-signalised junctions with an average daily traffic less than 10,000 vehicles to high traffic volumes at a number of signalised junctions with an average daily traffic of more than 30,000 vehicles. The selected junctions were mostly four-arm-junctions, two lanes in each approach on the major street and one lane per approach on the intersecting minor road at non-signalised junctions. The intersecting streets have two lanes in each approach at the signalised junctions.

Conflict data and some behaviour indicators were extracted from video recordings. The recordings lasted six hours daily and were performed for two days at non-signalised junctions and for three days at signalised junctions. Traffic volumes as well as the traffic composition data were also gathered from the video recordings. All injury accidents that were reported to the police at the selected junctions during five years (1993-1997) were collected.
Summary

For verifying the third hypothesis, a number of interviews were completed in both countries with pedestrians that were involved in conflicts. In addition, a number of selected conflicts that involved the interviewed pedestrians were edited and shown on two tapes for two groups of layman observers from both countries and a group of safety experts. They were asked to rate the severity of these conflicts.

The Analysis approach

Validating the traffic conflicts technique in Sweden

Two perspectives were considered for the verification of hypothesis 1:

- Definition of relevant road-user.
- Definition of conflicts that are accident related.

Two different definitions for the relevant road-user were introduced as follows:

High definition of RRU: the road-user whose speed at time of the first participant taking evasive action and the time remaining to accident produces the more severe conflict regardless of the performer of the evasive action.

Low definition of RRU: the road-user whose speed at time of the first participant taking evasive action and the time remaining to accident produces the least severe conflict regardless of the performer of the evasive action.

The second perspective considered an alternative definition for serious conflicts. Alternative definitions grouped under the following three different approaches were put forward:

- Threshold approach
- Severity index approach
- Sub-group approach

The Threshold approach

The alternative threshold definitions are based on the currently used concept to establish the definition of serious conflicts. This concept states that a limit should be drawn between serious conflicts and non-serious conflicts based on the speed and the TA-value of the involved road-users. Four alternative thresholds were investigated in addition to the present definition:
1. The threshold that is intersecting the X-axis of the TA-speed graph at 2.25 seconds (Threshold All)

2. The threshold that is intersecting the X-axis of the TA-speed graph at 1.0 second (Threshold GR3)

3. The threshold that is intersecting the X-axis of the TA-speed graph at 0.75 seconds (Threshold GR4)

4. The threshold that is intersecting the X-axis of the TA-speed graph at 0.25 seconds (Threshold GR6)

**The Severity index approach**

The main idea behind the introduction of this approach of analysis was to include other dimensions that depict the dynamic characteristics of vehicle-pedestrian conflicts in the Swedish TCT.

Conflict situations consist of three distinct phases, namely pre-conflict, the conflict, and post conflict. Each phase is described by a number of characteristics including the following:

- The type of vehicle manoeuvre: pre-conflict phase.
- Type of vehicle involved: pre-conflict phase.
- The complexity of situation: pre-conflict phase, including:
  - Possible time available for each road-user to see each other before being involved in the conflict.
  - A measure of exposure expressed by either an instant measure of exposure at a distinct time before the conflicts, or the change over time in the traffic exposure before the conflicts.
- The severity of conflicts based on the speed and the TA-value of the relevant road-users: conflict phase.
- The time that separates the involved road-users after the completion of the evasive actions: post-conflict phase.

Forty-three indices were introduced to re-scale the conflicts according to some or all the above characteristics. These indices were assumed to reflect how these characteristics are expected to influence the probability of accident had no involved road-users acted evasively to end the conflict. Only eight of the proposed indices were thoroughly investigated in the validity study.
c) Relating the probability of observing the actual number of accidents to the highest reported probability of observing the actual number of accidents among all investigated definitions.

d) Multiplying the ratios obtained in a) and b) and the inverse of c) would result in the overall ratio to the best and the target is to report the lowest overall ratio to the best for the most valid definition of conflicts.

**Validating the traffic conflicts technique in Jordan**

The second hypothesis was investigated based on verifying two sub-hypotheses. First, the most valid definitions in Sweden are not the most valid definitions in Jordan. Second, predictions that are based on conversion factors developed in Sweden are not as good as predictions based on conversion factors developed for Jordan.

To verify the first sub-hypothesis, accident to conflict conversion factors based on data collected were developed in Jordan. The same procedure used while developing an alternative definition of serious conflicts in Sweden was also used. Conflict and accident data at eight non-signalised junctions and at eight signalised junctions were utilised in developing accident to conflict conversion factors that corresponded to the tested definitions for each type of junction. To validate the proposed definitions of conflicts, accidents at three of the non-signalised and three of the signalised junctions were predicted. The predictions were further analysed to arrive at the most valid definition of conflicts for each type of junction in Jordan by considering the same procedure that was used for validating the proposed definitions in Sweden.

To verify the second sub-hypothesis, accidents at junctions in Jordan were predicted using conversion factors developed in Sweden and compared with predictions based on conversion factors developed in Jordan.

**Road-user perception of conflicts**

The verification of the third hypothesis was completed by considering:

1. Examining the difference between conflict characteristics recorded in Sweden and Jordan.

2. Investigating how the road-users involved in conflicts perceived these situations and assessed their severity.

3. Exploring how laymen coming from different traffic environments would assess the severity of conflicts that involved other road-users and were recorded in different traffic environments than their own.

The verification of the third hypothesis was completed by performing descriptive analysis of collected data in both countries. A number of analyses of variance (ANOVA) and correlation analyses were carried out.
Results

Improvement of the present Swedish TCT

The results of validating various different definitions under each approach of analysis as a means of improving the Swedish TCT provided different trends for each type of junction. The results were not in favour of one alternative definition of relevant road-user or to one common definition of conflicts as shown in Table 0.1

Table 0.1  A summary of the results of validating various definitions of pedestrian conflicts under each approach of analysis for non-signalised and signalised junctions, and both junction types together.
(The validity is the better, the smaller the ratio to the best is)

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Present definition</th>
<th>Threshold approach</th>
<th>Severity index approach</th>
<th>Conflict sub-group approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threshold RRU</td>
<td>Overall ratio to the best</td>
<td>Index RRU Overall ratio to the best</td>
<td>sub-group Severity group Overall ratio to the best</td>
</tr>
<tr>
<td>Non-signalised</td>
<td>GR5 Present 4.22</td>
<td>GR6 Present 2.3</td>
<td>DS41 Low 2.97</td>
<td>V≥20 High Serious 2.48</td>
</tr>
<tr>
<td>Signalised</td>
<td>GR5 Present 33.6</td>
<td>GR6 High 8.64</td>
<td>N321 High 48.8</td>
<td>TA ≤ 0.75 High All 17.78</td>
</tr>
<tr>
<td></td>
<td>GR5 High 9.67</td>
<td></td>
<td></td>
<td>V≥30 High Serious 22.02</td>
</tr>
<tr>
<td>All junctions types together</td>
<td>GR5 Present 4.41</td>
<td>GR6 Present 1.86</td>
<td>N321 High 2.29</td>
<td>TA ≤ 0.75 High All 1.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V≥20 High Serious 3.82</td>
</tr>
</tbody>
</table>

1) Listed severity indices were calculated by re-scaling the conflicts according to their severity grade, vehicle manoeuvre, vehicle type, time separating the involved road-users after the completion of evasive action, possible time available for the road-users to see each other before the conflicts and a measure of exposure expressed by either an instant measure of exposure at 3.2 and 1 seconds before the conflicts (N321) or the change over time in the traffic exposure measured 4 and 1 seconds before the conflicts (DS41).

According to Table 0.1 and based on the reported results in this study it is possible to conclude that the present definition of serious conflicts in Sweden could be improved by:

- Adopting the high definition of RRU in classifying the conflict severity at signalised junctions. The use of the high definition of RRU was also satisfactory with the conflict sub-group approach. The high validity of conflict sub-group based on the high definition of RRU was reported for each type of junction and for both junction types together. On the other hand, definitions under the threshold approach based on the present definition of RRU were the most valid definitions for non-signalised junctions. Nevertheless, some conflict sub-groups based on the high definition of RRU were among the most valid definitions of conflict for this type of junction.
Conflict sub-group approach

In this approach all conflicts that have one common characteristic were grouped into one category and were then related to accidents. The sub-groups were either formed by considering all recorded conflicts or serious ones only. The serious conflicts were defined according to the present definition, GR5.

More than 200 conflict sub-groups were formed, and only some of them were used in the present validity study, for instance:

- Sub-group $V \geq 20$ includes conflicts where the RRU’s speed was at least 20km/h.
- Sub-group $TA \leq 0.75$ includes conflicts where the RRU has a TA-value that does not exceed 0.75 seconds.
- Sub-group $TS113$ includes all conflicts where the RRU might be influenced by the presence of at least one, and not more than three other road-users measured one second before the conflict.

A number of conversion factors were developed based on various definitions of conflicts under the three investigated approaches and the alternative three RRU definitions. Conflict and accident data at seven non-signalised junctions and at seven signalised junctions were utilised in developing accident to conflict conversion factors that correspond to the tested definitions for each type of junction. To validate the proposed definitions of conflicts as an accident prediction tool, accidents at three of the non-signalised and three of the signalised junctions were predicted. The predictions were further analysed to arrive at the most valid definition of conflicts for each type of junction in Sweden by considering the following:

- The variance of accident to conflict conversion factors ($\pi$) and its relation to its value “coefficient of variation of $\pi$”. The target is to minimise its value.
- The predictions’ average coefficient of variation. The target is also to minimise its value.
- The probability of observing the actual number of accidents. The target is to maximise its value.

In order to combine these three criteria an “overall ratio to the best” concept was introduced. It was calculated for each definition as follows:

a) Relating the coefficient of variation of $\pi$ to the smallest reported coefficient of variation of $\pi$ among all investigated definitions.

b) Relating the average coefficient of variation of predictions to the smallest reported average coefficient of variation among all investigated definitions.
• Shifting the present threshold by 0.25 seconds to the more severe direction of TA-speed graph for signalised and non-signalised junctions and for all junction types together in Sweden.

• Excluding conflicts where the speed of the RRU is less than 20km/h. Sub-group V≥20 for serious conflicts defined according to the present threshold GR5 and, based on the high definition of RRU was found among the definitions that were considered as the most valid definitions for non-signalised junctions. Sub-group TA≤0.75 based on the high definition of RRU (all conflicts where the TA-value is not more than 0.75 seconds) was among the most valid definitions for accident prediction for signalised junctions. It was the most valid definition for both junction types together.

The application of the Swedish TCT in Jordan

The validity analyses in Jordan (see Table 0.2) showed that the conflict definitions most valid in Sweden were not the most valid in Jordan. This verified the first sub-hypothesis. Nevertheless, some definitions have a high validity in both countries, especially for non-signalised junctions if based on conflict sub-group approach.

Table 0.2 A list of the most valid definitions under each investigated approach for non-signalised and signalised junctions in Jordan, and all junction types together.

(The validity is the better, the smaller the ratio to the best is)

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Present definition</th>
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<th>Severity index approach</th>
<th>Conflict sub-group approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threshold RRU</td>
<td>Overall ratio to the best</td>
<td>Threshold RRU</td>
<td>Overall ratio to the best</td>
</tr>
<tr>
<td>Non-signalised</td>
<td>GR5 Present 39</td>
<td>GR3 High Present 33.55 S High 23.6 V≥20 High Serious 7.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signalised</td>
<td>GR5 Present 95</td>
<td>GR3 High Present 58.20 SC High 66.6 TSS113 High All 9.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All junction types together</td>
<td>GR5 Present 27</td>
<td>GR6 Present 15.99 SC Present 23.2 V≥30 Present Serious 3.35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Listed severity indices were calculated by re-scaled the conflicts according to their severity grade (S), and according to their severity grade and vehicle manœuvre (SC)

Table 0.2 indicates the following:

• The most valid conflict definitions for each junction type were those based on the high definition of RRU. It is the present definition of RRU that is linked to the most valid conflict definitions developed for both junction types together.
• Definitions under the conflict sub-group approach were the most valid for conflicts in Jordan. The most valid definitions were as follows:

☐ Conflict sub-group V≥20 for non-signalised junctions: It includes all serious conflicts categorised by the present threshold GR5 and high definition of RRU that involve a vehicle at a speed of ≥20 km/h or more.

☐ Conflict sub-group TSS113 for signalised junctions: It includes all serious conflicts categorised by the present threshold GR5 and high definition of RRU that involve a road-user interacting with at least one and not more than three other road-users measured one second before the conflict.

☐ Conflict sub-group V≥30 for both junction types: It includes all serious conflicts categorised by the present threshold GR5 and high definition of RRU that involve a driver using at least a speed of ≥30 km/h.

• Defining conflicts by alternative thresholds alone did not produce the most valid definition of conflicts. This was evident from the results reported at each type of junction as well as for both junction types together.

• Accidents for each type of junction in Jordan were predicted using conversion factors developed in Sweden and in Jordan. The results indicated the following:

• Accident predictions completed for signalised junctions in Jordan based on conversion factors developed in Sweden were not as good as the predictions based on conversion factors developed in Jordan. The same is applicable if the predictions were based on conversion factors that were developed for both junction types together.

• Results from non-signalised junctions varied according to conflict definition analysis approach. The predictions were very poor when the threshold approach was used. Conflict sub-group definition produced a higher probability of observing the actual number of accidents, but with a higher coefficient of variation.

Road-user perception of conflicts

There is a difference in the road-user perception of conflicts. They perceive the severity of conflicts they were involved in differently.

For instance, Swedish pedestrians do not act to avoid the consequence of conflicts as frequent as Jordanian pedestrians do. Vehicle-pedestrian conflicts in Jordan are characterised by close proximity between the involved road-users, and conflicts have a lower speed and lower TA-value in Jordan compared to Sweden.

Swedes either as pedestrians involved in conflicts or as conflict laymen observers were found to perceive the conflict severity lower than the Jordanians do. It might be a reflection of their perception that the traffic environment is safe and the situations that
they are involved in could be handled safely. They expect that the driver should comply with traffic rules and this makes the expectation higher. On the other hand, Jordanians believed that the crossing in traffic is always associated with high risk. They do not expect that the drivers would communicate with them safely. This is evident from their behaviour in traffic while being involved in conflicts. They tend to take evasive actions more frequent than Swedish pedestrians do, who do not feel that they are at high risk so they do not act.

Swedish pedestrians' recognition of being involved in conflicts was lower than the Jordanians pedestrians' recognition. Furthermore, most of those who recognised the conflicts in Sweden did not describe their involvement in conflicts as risky situations but as a matter of traffic law compliance. On the other hand, the Jordanians were not referring to the right of way problem. A high proportion of Jordanian responses raised an important issue when they pointed out that they were not paying enough attention in traffic (they were “in a hurry” or “talking to friends”). They tend to blame themselves for being involved in conflicts, which was not the case in Sweden.

Conclusions

The results indicated that the use of high definition of RRU in classifying conflict severity could improve the present definition of the Swedish TCT in relation to pedestrian conflicts. The vehicle speed and TA-value are used in defining the severity of conflicts. The driver is the relevant road-user. If we know more about the speed of the vehicle we will be able to judge the severity of an accident, if it would have happened. Injury accidents were considered in developing accident to conflict conversion factors ($\pi$). It is expected that classifying conflict severity based on some conflict characteristics such as vehicle speed that are closely related to the probability of injury accidents would produce better accident predictions. The use of the high definition of RRU implies shifting the conflict severity towards the more severe side of the TA-speed curves. The implication of shifting the conflict distribution to the more severe direction of the TA-speed graph (high definition of RRU) would increase the number of conflicts in high severity grades (grade 5 or more). Definitions based on threshold definitions (GR5, GR6) and the high definition of RRU produce sufficient number of conflicts in severe grades that are expected to produce high probability of observing the actual number of accidents with relatively small variations. The practical application of using the high definition would be to reduce the burden on the conflict observer, it is only the driver speed and distance to the potential collision point that are needed to be collected besides the occurrence of evasive action.

Threshold GR6, which produced the most valid definition of conflicts for accident prediction purposes at non-signalised and signalised junctions in Sweden, is believed to include situations that are accident like and could be used reliably in predicting accidents. If the present threshold is shifted by 0.25 seconds to the more severe direction of the TA-speed graph, fewer conflicts are included than today. The fewer the number of observations are the higher the variation. Therefore, predictions based on this threshold have a high probability of observing the actual number of accidents but with some variation.
The results also indicated that the present definition of serious conflicts in the Swedish TCT (threshold GR5) could be simply improved by excluding some conflicts involving drivers that have a speed that is less than 20km/h (conflict sub-group V≥20). Definition based on conflict sub-group V≥20 is interesting from the point of view that the observers are not collecting data about events that would not produce injuries in traffic. Conflicts involving road-users (drivers) that have a low speed might be high in number but they do not reflect a high probability of injury accidents.

The results indicated that only some definitions included in severity index approach produced slight improvements to the present definition of serious conflicts. The indices that produced such an improvements demand collecting sophisticated types of information that could not be collected on-site by observers. What we have achieved as an improvement does not seem to justify such a complicated process of collecting and analysing the data.

Developing a TCT as a tool that could be used in traffic safety analysis work is of great value in Jordan. It could be used for safety diagnosis and evaluation purposes as well as for accident predictions for similar junctions. The results indicated that in order to apply the technique, it is preferable to develop a definition that takes into consideration the local conditions and collecting the corresponding conversion factors. There are differences in conflict numbers and characteristics and accident numbers in the two countries, which may have affected the magnitude of accident to conflict conversion factors and their predictive power.

There is a difference in the road-users' perception of risk of their involvement in conflicts. Understanding the differences in the road-user perception of risk would provide insight into a possible means of influencing the road-user's behaviour. For instance, increasing the level of traffic safety awareness among Jordanian road-users is essential. Developing the infrastructure to influence the road-user behaviour is another issue that needs to be highlighted by the relevant authorities. Enforcing the traffic law is another aspect that should be considered in altering the road-user behaviour. In Sweden, the pedestrians’ high expectation of the safe environment in traffic is an issue that should be addressed.

**Future research work**

A number of potential areas for future research studies were highlighted as a consequence of this study:

The applicability of the high definition of RRU needs to be studied for vehicle-vehicle conflicts. Two issues need to be addressed. First, if this definition is applicable, secondly should we modify the definition of serious conflicts for vehicle-vehicle conflicts and whether that definition could be changed for different types of junctions? Investigating the validity of definitions based on sub-groups for vehicle-vehicle conflicts is also of interest.

The applicability of the Swedish TCT needs to be studied in Jordan for vehicle-vehicle conflicts. To be able to develop a comprehensive tool for safety assessment, there is a need
to consider vehicle-vehicle conflicts and develop and validate the related conversion factors.

The implication of the use of the high definition of RRU on the severity hierarchy for different types of junctions is an interesting issue. In addition, the severity hierarchy could also be investigated by considering conflict sub-groups.

Developing a definition for pedestrian conflicts for other types of junctions such as a roundabout or mid-block pedestrian crossing may be also of interest. This include the possibility of including more than one conflict character in forming the conflict sub-groups and how that could influence predicting the accidents for different types of junctions.

Due to practical constraints, the present study included only the pedestrians’ perception of conflicts. The drivers’ perspectives were not considered. For future work we need the perspectives of both pedestrians and vehicle drivers.

Change in road-user behaviour after passing the new legislation in Sweden on the priority of pedestrians over car drivers on zebra crossings and its implication on the safety hierarchy is of interest. Accident to conflict conversion factors at junctions with zebra crossing in Sweden might need modification based on the change of behaviour and its influence on the safety hierarchy.
<table>
<thead>
<tr>
<th>Glossary of terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident</td>
<td>Injury accident.</td>
</tr>
<tr>
<td>Collision course</td>
<td>The road-users would have collided had no road-user performed evasive action.</td>
</tr>
<tr>
<td>Conflict Severity</td>
<td>A measure of conflict severity based on combining the conflicting speed and the TA-value of the relevant road-user.</td>
</tr>
<tr>
<td>Conflict sub-group</td>
<td>Conflicts that have one common criterion among them.</td>
</tr>
<tr>
<td>Conflicting speed</td>
<td>Road-user' speed at the moment of performing evasive action.</td>
</tr>
<tr>
<td>Conflict type</td>
<td>Vehicle-pedestrian conflict.</td>
</tr>
<tr>
<td>Conversion factors (π)</td>
<td>Accidents to conflicts ratio.</td>
</tr>
<tr>
<td>CoV</td>
<td>Coefficient of variation.</td>
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<tr>
<td>Evasive action</td>
<td>A precautionary action like changing speed or direction that is made to avoid a possible collision.</td>
</tr>
<tr>
<td>GNP</td>
<td>Gross National product.</td>
</tr>
<tr>
<td>High definition</td>
<td>the road-user whose speed at time of the first participant taking evasive action combined with the time remaining to the potential collision produces the most severe conflict regardless of the performer of the evasive action.</td>
</tr>
<tr>
<td>of relevant road- user</td>
<td></td>
</tr>
<tr>
<td>K-S</td>
<td>Kolomogorov-Smirnov test.</td>
</tr>
<tr>
<td>Layman group</td>
<td>A group of observers that have not been trained as conflict observers.</td>
</tr>
<tr>
<td>Low definition</td>
<td>the road-user whose speed at time of the first participant taking evasive action combined with the time remaining to the potential collision produces the least severe conflict regardless of the performer of the evasive action.</td>
</tr>
<tr>
<td>of relevant road- user</td>
<td></td>
</tr>
<tr>
<td>M-W</td>
<td>Mann-Whitney test.</td>
</tr>
<tr>
<td>Perception of risk</td>
<td>The subjective risk which is meant to describe the feeling of danger the road-users get when they are involved in a conflict.</td>
</tr>
<tr>
<td>P(X)</td>
<td>Probability of observing the actual number of accidents given the estimated number of accidents.</td>
</tr>
<tr>
<td>Relevant road-user (RRU)</td>
<td>The road-users who defines the severity of conflicts, the Present definition of relevant road-user is the road-user who made an evasive action and for whom the combined conflict speed and TA-value produced the least severe conflict.</td>
</tr>
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<td>-------------------</td>
<td></td>
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<tr>
<td>Severity grade</td>
<td>Uniform severity zones (Severity zones) are defined as the area that is limited by two severity levels on the TA-speed graphs.</td>
</tr>
<tr>
<td>Severity index</td>
<td>A possible way to understand the conflict event is by viewing the conflict as dynamic situation.</td>
</tr>
<tr>
<td>TA-speed graph</td>
<td>A layout that is intended to relate the TA-value to the conflicting speed that has a theoretical basis.</td>
</tr>
<tr>
<td>TA-value</td>
<td>Time to accident is the time that remains to an accident at the moment when evasive action has just been started, presupposed that the road-users continued with unchanged.</td>
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<tr>
<td>TCT</td>
<td>Traffic conflicts technique.</td>
</tr>
<tr>
<td>TTC</td>
<td>Time to collision, i.e. time that remains to a collision, presupposed unchanged speeds and directions (continuous over time).</td>
</tr>
<tr>
<td>Uniform severity level</td>
<td>Uniform severity level on the TA-speed curves that is defined based on some theoretical approach to define the threshold that differentiates serious conflicts from the rest or any threshold that is parallel to it.</td>
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<tr>
<td>( \hat{\lambda} )</td>
<td>Predicted number of accidents.</td>
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1 Introduction

1.1 Background

The World Health Organisation (WHO) considers road fatalities and road accident-related injuries a leading health care concern at present. Over 700,000 people are killed in road traffic accidents every year world-wide, some estimates put it up to over a million (Blomberg, 1999). The number of injured is likely to be above 10 million. The global socio-economic costs of road traffic accident are estimated to exceed 500 billion US$.

The developing countries are suffering the most; more than seventy per cent of all road accident fatalities are reported there. Thirty to forty per cent of traffic fatalities in developing countries are pedestrians. The proportion in Jordan, a developing country, is over forty per cent. Half of them are under the age of 15 years and two thirds under the age of 25 years. The socio-economic costs of road traffic accidents mount to over 2 percent of the Gross National Product (GNP) in a number of developing countries (Jacobs et al., 2000). These countries have very limited resources. Their costs in traffic accidents ought to be saved for the welfare of their nations.

To address the safety problem there is a need to identify the factors that might cause the problem. Police reported accident statistics are traditionally used as a basis for safety studies at macro and micro level. Safety studies are normally performed by considering either the accident data alone, or combined with road-user behaviour data, which could be considered on its own as a method of evaluation. Accident data is usually preferred to behaviour data because it reflects what happened in reality and what could have been avoided. Accident data is often related to other variables that might influence the probability of accident by means of descriptive analysis (Ekman and Draskóczy, 1989; Salonen 1991, cited in OECD, 1998; Sjögren et al., 1993; Cambon de Lavalette, 1994; Fontaine, 1995; Heine et al., 1998; Stutts et al., 1996; Scaramuzza, 1998). Alternatively, accident data could be used to establish statistical models that can be utilised to identify hazardous locations (Kimber and Kennedy, 1988; Davis et al., 1989; Nilsson, 1994; Harland et al., 1996; Leden, 1997; Hunt, 1998,1999).

Accident statistics could be supplemented by other types of accident data that might help in identifying the causal factors of accidents. For example, the police accident statistics could be expanded to include a larger number of variables that describe each accident and its consequences. This is often referred to as the intermediate accident analysis approach. The data collected for this approach is more detailed than data extracted from the standard accident statistics nonetheless it is not a complete description of the accident processes (OECD, 1998). Alternatively, in-depth accident investigation studies could be used to understand the accident mechanism and to identify the factors that influence it. A detailed accident investigation may be undertaken immediately after an accident to reconstruct it. However, these studies have their own limitations regarding the generalisation of the obtained results as only a small number of accidents form the basis for the analysis (Carsten et al., 1989 cited in Oppe, 1993; Salusjärvi, 1989; Girard, 1993; Ahlcrona et al., 1994, cited in OECD, 1998).
Accident based safety analyses suffer from bias due to the serious under-reporting problem (Hauer and Hakkert, 1988; Grayson and Hakkert, 1987; Mazlumol-Hosseini, 1991; James, 1991; Polak and Oppe, 1997). The regression to the mean effect associated with accident data reflects the random nature of accidents and induces additional bias. Moreover, information about events preceding accidents is usually missing and the fact that accidents by default are rare events complicates the matter more.

Behavioural data combined with accident data provide an insight into the probable causes of accidents and enable the analyst to understand the mechanism that might lead to an accident. Three techniques are normally used to evaluate the road-user behaviour (Oppe, 1993):

- Observation techniques are carried out in real traffic or from video recordings. They include traffic conflict techniques, speed measurements, and interaction studies.
- Verbal techniques are expected to assess the road-users reflections in traffic, their attitude, and how they perceive certain events in traffic. They include direct interviews or filling in questionnaires. (Steyvers cited in Oppe, 1993).
- In the experimental techniques, a hypothesis concerning certain road-user behaviour is formulated. All the relevant factors that are required to verify it are defined and investigated; other factors should be controlled. There are two approaches for the application of the experimental techniques; the simulation experiments (Nilsson and Alm, 1991) and experiment in real traffic (Himanen et al., 1995; Beilinson and Rathmayer, 1999).

Observation techniques are commonly used to perform behavioural studies. They are usually conducted at micro level, i.e. junction (Hydén, 1987), mid-block pedestrian crossing or on some driving routes (Güttinger 1982, 1984; Rissler, 1985). Traffic conflict studies are a form of behavioural studies that received considerable interest during the last three decades (Kraay, 1983; Asmussen, 1984; Van der Horst and Kraay, 1986; Hydén, 1987; Seco et al., 1991 Linderholm, 1992; Lord, 1994,1996). Other types of behavioural studies as speed and interaction studies are often used for safety assessment purposes (Jones, 1980; Himanen and Kulmala, 1988; Kulmala and Beilinson, 1991; Janseen and Van der Horst, 1994; Ewert, 1995; Hine and Russell, 1996; Várhelyi, 1998).

It is envisaged that these types of studies, particularly conflict studies, are describing events that depict unsafe manoeuvres. Their frequent occurrence at a given entity is more likely to indicate that the accident is probable.

1.2 The Traffic Conflicts Technique (TCT)

The interest in traffic conflicts technique has been growing since it was introduced in the USA by Perkins and Harris (1967) of General Motors (GM). A number of different traffic conflict techniques were established in Europe and America but with varied definitions and observation procedures (Older and Shippey, 1980; Glauz and Migletz, 1980; Baguley, 1984; Brown et al., 1984; Mattsson, 1983 cited in Mattsson, 1984; Glauz, 1985; Van der Horst and Kraay, 1986; Swain, 1986, 1987; Parker et al, 1989).
The first common definition of a traffic conflict that was agreed upon internationally (Amundsen and Hydén, 1977) is:

"A traffic conflict is an observable situation in which two or more road-users approach each other in space and time to such an extent that a collision is imminent if their movements remained unchanged"

The traffic conflict techniques (TCT) that were developed in different countries are classified as being either subjective or objective. The techniques that are in use in France (Muhlrad, 1982; Muhlrad and Dupre, 1984), Germany (Erke, 1984), UK (Baguley, 1984), and USA (Migletz and Glauz, 1984) are subjective since they employ observers who detect the conflicts and assess the severity according to their perceptions. They are expected to incorporate their impression and personal evaluation and this is frequently open to criticism (Williams, 1981). Techniques like the Dutch (Van der Horst, 1982; Van der Horst and Kraay, 1986), and the work of Hupfer in Germany, (Hupfer 1995, 1996, and 1997) are considered to be more objective. They are based on indicators such as time or distance that are measured with objective means (i.e. image processing). Other techniques like the Swedish (Hydén, 1977, 1987) and the Canadian (Brown et al., 1984; Brown, 1986, 1989) are based on objective indicators such as speed and time, which are assessed subjectively.

Conflicts are accident like but far more frequent in number than injury accidents or even than property damage accidents. By applying a traffic conflicts technique statistically enough data could be collected in a relatively short time. The data is recorded and detailed according to the requirement of the study. Trained observers collect the data. They will not bear any legal responsibility for observing and recording conflicts, unlike the parties that are involved in accidents who might incur legal penalties. Trained observers are experts who have the competence to detect the relevant situation and use the best technical terms that describe the situation. On the other hand, collecting enough conflict data might be expensive to carry out if observations are made over a long period of time. The utilisation of human observers is expected to induce a subjective element into their observations and unfortunately, it is unavoidable.

The basic assumption behind the introduction of a traffic conflicts technique was conflicts occur more frequently than accidents. Studying conflicts would provide the possibility of investigating traffic safety conditions at any site without waiting for accidents to happen. Several studies were conducted in the industrialised countries and to a lesser extent in the developing countries aimed to validate the technique as a surrogate for accidents. This is often referred to as external, or product, or predictive validity of the technique (Spicer 1971, 1972, 1973; Zimolong et al., 1980; Migletz et al., 1985). Researchers have investigated the validity of different techniques and came up with contradicting results. Some researchers believed that it is a valid tool for accident prediction purposes (Hydén 1987; Grayson, 1986; Grayson and Hakkert, 1987) while others argued the opposite based on their review of the published literature (Glennon et al., 1977, Williams 1981, Pfundt cited in Hupfer 1996). Poor quality of accident data and the random nature of accident and conflict data may have contributed to the low correlation values that were reported. Particularly when conflicts were related to accidents
in an attempt to validate the traffic conflicts techniques during the seventies and early eighties (Engel, 1985). The controversy over the validity of the technique did not settle until Hauer and Gårder (1986) presented their contribution to the validity issue. They pointed out that because of the inherent random variability in accident numbers, conflicts could only be used to estimate the expected number of accidents and not the actual number.

Internal validity is supposed to provide insight into the traffic conflict concept. It covers issues related to conflict theories, definitions, and observation procedures (Allen and Shin, 1977; Hauer, 1977; Spicer et al., 1980). Internal validity is equivalent to the reliability of the technique (Hydén and Draskóczy, 1991). There are two types of reliability that are often discussed, internal and external reliability. Internal reliability tests how reliable the observers are in scoring conflicts (Zimolong et al., 1980; Brown et al., 1984; Kulmala, 1984; Hydén, 1987). The results of these studies showed that conflict observers are reliable in detecting and scoring conflicts. External reliability investigated the reliability of the observers’ scoring of conflicts compared with an objective measure of the conflicts (Grayson, 1984; Shinar, 1984; Van der Horst, 1984; Kraay, 1985; Kruysse, 1991; Kruysse and Wijhuizen, 1992). The reported results were not as good as those reported for the internal reliability test.

The traffic conflicts technique has been applied as a predictive tool for the expected number of pedestrian accidents at transport system units by a large number of researchers (Cooper, 1973; Paddock, 1974; Zimolong, 1980; Hydén, 1987; Davis et al., 1989; Linderholm, 1992; Lord, 1994). The traffic conflicts technique is also used as a safety diagnostic tool or as a safety evaluation tool (Grayson, 1984, 1986; Zimmermam, 1986; Muhlrad, 1986). Observing the road-users' behaviour in real traffic enables the safety appraiser "expert" to diagnose the safety problem in short time instead of waiting years for accidents to happen (Zimolong et al., 1980; Cynecki, 1980; Zegeer et al., 1980; Güttinger, 1982, 1984; Javid and Seneviratne, 1991; Lord, 1996). The use of the traffic conflicts technique as a safety evaluation tool provides information about the effectiveness of traffic safety measures immediately after their implementation. This eliminates the interference of other factors that might have influenced safety conditions (Albrecht, 1982; Kulmala, 1982; Hydén et al., 1982; Brown, 1986; Almqvist, 1989 cited in Draskóczy, 1990; Lukaschek et al., 1986 cited in Draskóczy, 1990; Gårder, 1989; Zuzan, 1991; Clark et al., 1996; Houten et al., 1997; Zein et al., 1997). This problem is often raised when accident statistics are used for evaluation.

The application of traffic conflicts technique in developing countries is not as prevalent as in the industrialised countries. Few studies have dealt with the vulnerable road-user problem, particularly the pedestrians (Almqvist and Hydén, 1994; Fazio and Tiwari, 1995; Pires Guedes et al., 1997). Other studies were reported from some developing countries for the use of traffic conflicts technique for accident predictions and for safety diagnostic purposes (Tanvir, 1983; Ghareir, 1985; Muhlrad, 1987, 1989; Shbee, 1992; Salman and Al-Maita, 1995).

The first use of traffic conflicts technique in Sweden was to evaluate the effectiveness of implementing area-wide traffic management schemes in the centre of two cities (Lund and Uppsala in the early 1970's). According to the basic hypothesis in the Swedish traffic
conflicts technique, the interaction between road-users in the traffic process is a continuum of events that occur with different degrees of probabilities and seriousness. The severity of conflicts was first defined by considering a time measure (time to accident). It is the time that remains to an accident from the moment when evasive action has just been started presupposed that the road-users continued with unchanged speeds and directions. A time to accident of 1.5 seconds was considered as the threshold that differentiates serious from non-serious conflicts.

The technique was in operation in 1977 and it is often referred to as the "original technique" (Hydén, 1977). Linderholm developed the technique further, by reconsidering the definition of serious conflicts as a speed and time dependant (Linderholm, 1981 cited in Linderholm, 1992). Hydén proceeded in developing a modified version of the technique by considering a number of alternative definitions of serious conflicts. Some of the investigated definitions took into account the need to consider the speed and time in rating conflict severity. Others were based either on a time or speed measure. Hydén (1987) established a modified definition that was validated using the "process validity" concept that was first introduced by him. Svensson pursued the work of Hydén and attempted to validate the technique as an accident predictive tool using the procedure of Hauer and Gärder (1986). This work was not published, but presented in an internal report (Linderholm, 1992). The Swedish traffic conflicts technique was used safety diagnostic purposes and for safety evaluation purposes as well as for accident predictions. It performed well during its years of applications. Nevertheless, the long-term experience in technique as a tool for defining pedestrian safety problems showed that conflicts involving pedestrians appeared less serious than they might be.

The modified technique (The present technique as described through this dissertation) was still subjective until the early nineties. When the experts at Lund Institute of Technology [Lunds Tekniska Högskola (LTH)] began to evaluate a semi-objective technique for detecting conflicts. They aimed to develop a fully automated technique using an image process approach (Odelid and Svensson, 1993; Andersson and Odelid, 1997; Andersson, 1999).

The Swedish traffic conflicts technique has been applied in a number of European including Finland, Belgium, Portugal, and the UK. It was also applied in some developing countries specifically, Jamaica and Bolivia. It was not applied in large-scale studies. Operational conditions were observed at some locations to evaluate the implementation of some remedial measures that were intended to alleviate the hazards at the treated sites. It was also used for diagnostic purposes but not for accident prediction purposes and no validation studies were reported in this context.

The use of a traffic conflicts technique for safety evaluation in Jordan started in 1985. Traffic conflicts technique was used to evaluate the operational traffic conditions at roundabouts (Ghareir, 1985). The GM definition of conflicts was used, no severity scale was considered. Later, a modified version of GM definition was used after incorporating a severity scale suggested by Baguley (1984) to evaluate safety conditions at eleven four-leg non-signalised junctions in Amman (Shheeb, 1992). The correlation between accidents and conflicts was investigated, and a high correlation coefficient was obtained between serious conflicts and accidents (correlation coefficient of 0.96). Salman and AL-Maita
(1995) applied the traffic conflicts technique based on GM definition at three-leg non-signalised junctions. The conflict-traffic volume relationship was investigated and a linear relationship was evident for the selected junctions. They also concluded that conflicts are correlated to accidents. In all the above mentioned studies conflicts between motor vehicles were investigated. Conflicts where pedestrian are involved were not considered.

1.3 Purpose and scope of the study

The main purpose of this study is to investigate the potential means to improve the present Swedish traffic conflicts technique. A number of issues are to be addressed to achieve this objective. The relevant road-user concept currently used to classify the severity of conflicts, could be modified by considering alternative definitions. Second, alternative definitions for describing conflicts under three alternative approaches are considered. The first alternative approach includes definitions that are similar to the present definition of serious conflicts but amended to include alternative thresholds that differentiates serious conflicts form non-serious conflicts. The second alternative approach includes definitions that are aimed at visualising the conflict as a dynamic event. This implies the inclusion of additional information about the phase that preceded the conflicts, as well as the phase that followed the conflicts. The third alternative approach includes definitions that are based on forming conflict sub-groups that have one accident-related criterion.

The application of the Swedish traffic conflicts technique in Jordan is another purpose of this study. The validity of a traffic conflicts technique as accident prediction tool by considering the local conditions in Jordan is investigated.

A virtual purpose of this study was to look at the differences between the traffic environments in the two different countries. Sweden has a high level of motorization, an infrastructure of high standards, and road users who have high level of safety awareness. By comparison, Jordan has a moderate level of motorization and an infrastructure of acceptable standards, and road users with poor safety awareness.

This research is based on field studies that were performed in traffic at urban junctions. The study was conducted at twenty junctions in Sweden, ten signalised and ten non-signalised junctions. In Jordan, the study included twenty-two junctions, eleven signalised and eleven non-signalised. All police reported injury accidents at the selected junctions were collected. Traffic conflict, the investigated aspect of traffic behaviour and volume data were collected manually via video recordings made at the junctions under study. A number of interviews with road-user (conflict participants) were performed to examine their perception of conflict severity. The severity of some conflicts was rated by three groups of observers, expert and two layman observer groups from Sweden and Jordan.
1.4 **Topics to be covered**

This thesis is organised as follows:

**Chapter One:** introduction.

**Chapter Two:** presents an overview of traffic safety evaluations in different traffic environments. A comparison of the traffic safety conditions in Sweden and Jordan is included.

**Chapter Three:** The Swedish traffic conflicts technique is presented. The basic concepts that constitute the present Swedish traffic conflicts technique are highlighted including their operational use. The reliability and validity issues are also presented by making a clear distinction between the product validity and the process validity. The main problems encountered during the application of the Swedish traffic conflicts technique are discussed.

**Chapter Four:** The main hypotheses to be tested are introduced. The first hypothesis investigates the possible means for improving the Swedish traffic conflicts technique to address the pedestrian conflicts. The second hypothesis addresses the applicability of the Swedish traffic conflicts technique in Jordan. The third hypothesis was formulated to test if the conflict characteristics and the road-users' perception of these characteristics differ due to the traffic environment.

**Chapter Five:** It covers the data collection procedures. An overview of the study design is presented. Definition of factors and variables used in the study are presented as well as the adopted procedures for their measurements.

**Chapter Six:** It describes the methods used in processing the collected data, including the conflict and traffic volume data. The second part of this chapter deals with analyses methods that were used to verify the hypotheses.

**In Chapter Seven:** It discusses in detail the development of a modified version of the Swedish traffic conflicts technique to be used in vehicle-pedestrian conflicts. In addition to the present definition of the relevant road-user, two other alternative definitions are presented. Alternative conflict definitions are grouped under three alternative approaches of describing the conflicts. The threshold approach that is based on differentiating between serious and the non-serious conflicts was the first considered approach. The introduction of a conflict severity index was another alternative approach that was considered and was aimed to describe the conflict as a dynamic process. Conflicts are seen as a chain of events that start before the evasive action is taken, which normally defines the conflict occurrence, and the situation after completing the evasive action. The third approach was conflict sub-group. It implies classifying the conflicts in sub-groups that have one common criterion (that describes one conflict characteristics) that is believed to be accident related.
The final part of chapter seven covers the applicability of the Swedish traffic conflicts technique in Jordan and investigates the need to modify the technique to meet the local conditions.

Chapter Eight: It deals with traffic environment differences. Similarities and differences between road-users’ behaviour, when being involved in conflict, in both countries are discussed in detail. The road-users perception of conflict severity is also examined from two perspectives (the road-users who are involved in conflicts or the laymen who are observing conflicts).

Chapter Nine: The thesis is completed by a discussion of the main conclusions and recommendations for future work in this field. Based on the outcome of this thesis, new avenues are expected to generate further interests in the future.
Chapter Two
Traffic safety conditions in different environments

2 Traffic safety conditions in different environments

2.1 Comparison of safety conditions in different traffic environments

It is known that many differences exist between countries including population characteristics, geographical conditions and climate, transport infrastructure including road network and vehicles characteristics, traffic legislation and enforcement. These differences influence the traffic environments in different countries and make comparing traffic safety conditions subject to criticism. However, it is worthwhile comparing traffic safety conditions in the different countries. The main purpose of performing such comparisons at an international level is to measure the existing safety conditions in relation to other similar conditions. In addition, the comparison could be made between developing and industrialised countries that are perceived to high safety levels. These comparisons provide direction to future efforts in planning and implementing different safety schemes.

Different indicators could be used for comparing traffic safety conditions in different traffic environments. Each indicator is directed towards investigating the road safety conditions from a different perspective. For example, the number of fatalities per 1,000 registered vehicles or per 100 million vehicle/pedestrian kilometres travelled is supposed to reflect how safe the transport system is. On the other hand, the fatalities per 100,000 inhabitants measure the effect of road accidents on the safety of the population, which illustrates that road accidents are a health problem. The fatalities in traffic are used because they are believed to have a higher reporting level than injuries (Harris and Wegman (1991)).

2.1.1 Degree of motorization-fatality rate relationships

Researchers often relate road accident fatalities to traffic exposure. Number of fatalities is expected to increase as the traffic exposure increases, but up to a certain limit when the increase in traffic would not produce any increase in fatalities. At micro level (junction, roundabout, road-section, etc.), this limit is met in congested conditions because the traffic is standstill or moves at a very low speed. On the other hand, at macro level (country, region, city, etc), the degree of motorization (vehicles per 1,000 inhabitants) reflects the exposure.

The exposure present in vehicles per 1,000 inhabitants is widely used to compare traffic safety conditions for different countries because the number of registered vehicles is recorded reliably. In fact, collecting information about vehicle/pedestrian kilometres travelled is considered the most relevant type of information to be used in this kind of analysis. However, it demands allocating high resources, and the quality of data maybe dubious.

Smeed in 1949 related the fatality rate expressed as the number of fatalities per number of motor vehicles to the degree of motorization defined by the number of vehicles per inhabitant. Based on the 1938 data that mostly came from European countries Smeed
suggested the following relationship (Smeed, 1949 cited in Carlsson and Hedman, 1990):

\[
\frac{F}{V} = a \left( \frac{V}{P} \right)^b
\]

Where,
- \(F\): Number of fatalities per year
- \(V\): Number of motor vehicles
- \(P\): Population
- \(a\) and \(b\): regression constant

Jacobs (1982, 1986) developed further Smeed’s work by considering this relation for the industrialised and developing countries for the period 1970-1980. In one of his studies he indicated that the traffic safety situation in the industrialised countries in 1938 is similar to that in the developing countries in 1980 (Jacobs, 1986).

For the purpose of this study, data from a number of different countries with various degrees of motorization were collected and related to the number of reported fatalities. Two indicators were used the fatalities per 1,000 vehicles and fatalities per 1,000 inhabitants (Figure 2.1).

![Figure 2.1](image-url)  
**Figure 2.1**  The relationship between fatality rates and vehicle ownership levels in a number of industrialised and developing countries.
Figure 2.1 suggests that the developing countries that have a low level of motorization (less than 300 vehicles per 1,000 inhabitants) have a higher number of fatalities per 1,000 vehicles compared to the industrialised countries that have high levels of motorization (more than 400 vehicles per 1,000 inhabitants). On the other hand, the fatality rate per 1,000 inhabitants in the developing countries is, in general, slightly higher than the fatality rate in the industrialised countries. This might indicate that the size of traffic accidents in developing countries as a health problem is not as large as the transport problem. Furthermore, Figure 2.1 also indicates that the differences in the two indicators are higher for developing countries. For example, the fatalities rate per 1,000 inhabitants in Jordan (a developing country) is 0.13 and the fatality per 1,000 vehicles is 1.12, while the corresponding figures in Sweden (an industrialised country) are 0.06 and 0.12.

Another approach to investigate the relationship between degree of motorization and safety conditions was discussed by Rumar (1988). He estimated how many vehicles are needed in various countries to kill a person every year. The answer to the question is reported in Table 2.1, which was updated for some countries by the author based on 1996 statistics.

Table 2.1  Number of vehicles needed to kill a person every year in countries with different degree of motorization.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of vehicles needed to kill a person 1988</th>
<th>Vehicle ownership level 1988</th>
<th>Number of vehicles needed to kill a person 1996</th>
<th>Vehicle ownership level in 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>4,500</td>
<td>&gt;30</td>
<td>7,800</td>
<td>45</td>
</tr>
<tr>
<td>United States</td>
<td>4,000</td>
<td></td>
<td>5,000</td>
<td>78</td>
</tr>
<tr>
<td>of America</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United kingdom</td>
<td>3,500</td>
<td>-10</td>
<td>6,700</td>
<td>41</td>
</tr>
<tr>
<td>Germany</td>
<td>3,000</td>
<td></td>
<td>5,300</td>
<td>56</td>
</tr>
<tr>
<td>France</td>
<td>2,500</td>
<td></td>
<td>3,800</td>
<td>52</td>
</tr>
<tr>
<td>Greece</td>
<td>1,000</td>
<td></td>
<td>2,500</td>
<td>50</td>
</tr>
<tr>
<td>Hungary</td>
<td>1,000</td>
<td></td>
<td>2,200</td>
<td>29</td>
</tr>
<tr>
<td>Portugal</td>
<td>1,000</td>
<td></td>
<td>2,100</td>
<td>44</td>
</tr>
<tr>
<td>Jordan</td>
<td>700</td>
<td>8.3</td>
<td>520</td>
<td>8.0</td>
</tr>
<tr>
<td>Korea</td>
<td>125</td>
<td></td>
<td>950</td>
<td>26</td>
</tr>
<tr>
<td>Kenya</td>
<td>100</td>
<td></td>
<td>150</td>
<td>1.4</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>75</td>
<td></td>
<td>50</td>
<td>0.2</td>
</tr>
<tr>
<td>Pakistan</td>
<td>60</td>
<td></td>
<td>570</td>
<td>1.8</td>
</tr>
<tr>
<td>Nigeria</td>
<td>35</td>
<td></td>
<td>150</td>
<td>1.2</td>
</tr>
</tbody>
</table>

\[ a) \text{Kåre Rumar, Ergonomics, 1988.} \quad b) \text{Jacobs et al., 2000.} \quad c) \text{1997 Public security directorate (PSD).}\]
Table 2.1 indicates that as the degree of motorization is higher, the number of vehicles needed to kill a person becomes higher too. If 1988 statistics are compared to 1996 (Table 2.1), it suggests that the degree of motorization in some of the Asian and African countries was growing but not as fast as in the Eastern and Southern European countries (ESEC). The number of vehicles that were needed to kill a person in the ESEC has almost doubled if 1996 is compared to 1988 statistics in the ESEC. This was not the case for most of Asian and African countries. In the industrialised countries, the degree of motorization is also growing, but not to the same extent as the developing countries. Nevertheless, the number of vehicles that are needed to kill a person has also doubled. This implies that these countries are exerting efforts to reduce the size of the safety problem.

For the purpose of this study, the safety situation in Sweden is compared to that in Jordan. The vehicle ownership level in Jordan in 1996 is 77 vehicles per 1,000 inhabitants, whereas it is 450 in Sweden. The corresponding vehicle ownership levels in 1988 statistics were 444 and 83 for Sweden and Jordan respectively. The number of vehicles that were needed to kill a person in Sweden (based on 1996 statistics) was 7800 compared to 520 in Jordan. The corresponding vehicle numbers in 1988 were 4500 and 700 for both countries respectively. This implies that the traffic safety conditions are improving in Sweden while declining in Jordan.

Another contribution in this field came from the Netherlands. Oppe (1989) investigated the development of traffic volume over a number of years and its relation to traffic safety conditions expressed as the fatality rate (fatalities per traffic volume) in Netherlands, Germany, United Kingdom, and the United States of America. Oppe assumed that S-shaped logistic curves could be used in describing the development of traffic volume (degree of motorization). He suggests that the development of motorization initially increased slowly with time. It usually continues to increase but at a higher rate than the earlier development stage until a degree of saturation is reached when there is still increase in the vehicle ownership level, but not as rapid as before. It is expected that the fatality rates would decrease with time as the degree of motorization increases. Fatality rates, expressed as the number of fatalities per 0.1 million vehicles or any other measure of exposure) are assumed to follow negative exponential function. The decrease in fatality rate was interpreted at the Institute for Road Safety Research in the Netherlands (SWOV), as the “learning curve for the society”. It resulted from a combination of all efforts made to improve safety conditions, including improving the road system, legislation, education etc. (SWOV, 1986 cited in Oppe, 1989).

2.1.2 Comparison of accidents in industrialised and developing countries

It is common to investigate the national reported road traffic accident statistics when comparing the safety conditions in different countries. Access to these statistics in most cases, particularly for industrialised countries, is available direct via international databases. However, there are problems associated with these kinds of statistics, mainly due to the different types of reporting systems used. Sometimes it is difficult to compare different indices, simply because matching data are not always available. Underreporting is another problem that should not be over looked.
The reviewed literature indicates that the safety differences between industrialised countries have been widely investigated. (Mazlumol-Hosseini, 1991; Hagenzieker 1996; OECD, 1998; Saraj and Wright, 1999). Few studies were reported regarding the differences between industrialised and developing countries, which in this particular study includes the former Eastern European countries since the adopted criterion for the grouping countries is the traffic safety level. Below are some examples of the studies that were reviewed to explore the differences between safety conditions in industrialised and developing countries with an emphasis on the pedestrian problem.

A comparison of the safety conditions was made between developing and industrialised countries by exploring the general trend in fatalities and defining the road-user category at the highest risk. The study indicated that while pedestrian fatalities account for 20 per cent of all fatalities in traffic in Europe or the United States of America, they account for around 50 per cent in the Middle Eastern countries. The authors attributed this to the differences between traffic and population characteristics (Downing et al., 1991).

Road accident problems in specific cities in developing countries were also investigated in relation to the situations in industrialised countries. The distribution of accidents by type of road, class of road user, and type of involved vehicles was outlined. The results indicated that in the cities studied, the road accident fatality rates (per licensed vehicle) were up to thirty times greater in developing countries. In Amman, Jordan the fatality rate per 10,000 vehicles was 45 compared to 1.4 in Tokyo, Japan. The results also indicated that pedestrian casualties in Amman constitute 66 per cent of casualties in traffic while they constitute only 24 per cent in Tokyo (Jacobs and Sayer, 1984).

A comparative study on the road safety differences between two neighbouring countries, Estonia and Finland, was made. Before the World War II they had nearly the same economic level. During the post war era Estonia was left behind Finland in all fields including traffic safety conditions. According to the study, the Estonian road user risks expressed in fatalities per 100,000 inhabitants are higher than in Finland: pedestrians 4.1 times, car drivers 2.1 times, car passengers 2.7 times, and motor cyclists 2.2 times (Pihlak and Antov, 1999)).

Saraj and Wright (1999) introduced a model to measure the magnitude of the highway safety problem in different countries on a scale concept analogous to the Richter scale in seismology. They proposed to call it as “Sarja Scale for International Highway Safety.” The scale is logarithmic and consists of six grades. It was developed based on data from 14 European countries and the United States of America. According to the study the Norwegian, British and Swedish roads ranked 1st, 2nd, and 3rd safest respectively and it is only Norway that is located inside the relatively low risk zone. The co-author also investigated the size of the problem in five developing countries and found that Morocco, Turkey, Egypt, Ecuador and El-Salvador are all inside the highly dangerous zone.

The size of the accident problem at a global level was investigated (Jacobs, 2000), based mainly on 1996 statistics. Fatalities in traffic and information about the vehicle ownership level in most countries were presented in this study. It touched also upon the issue of accident under-reporting in different countries. The study showed that the
traffic safety situations are very serious in most of the developing countries, fatality rates (fatalities per 1,000 vehicles) were much higher than the rates in industrialised countries.

2.1.3 Comparison of road-users' behaviour in industrialised and developing countries

Observing traffic through the application of traffic conflicts techniques or other behaviour studies is a valuable source of information. They need co-ordination between the interested parties in different countries and require financial support. Limited studies were carried out to compare road-user behaviour in different traffic environments by using any of these techniques.

Most of the reported studies that dealt with these topics investigated the differences between some of the industrialised countries. Few investigated the differences between industrialised and developing countries. For instance, conflict studies concerning vulnerable road-users were completed in a number of European countries as part of Drive I and II projects in connection with other behavioural studies (Ekman and Draskóczy (eds.) 1992; Carsten et al., 1992; Westra and Rothengatter, 1993; Ekman et al., 1994; Ekman, 1994 cited in Kronborg and Ekman, 1995; Carsten, 1995). Another study explored the differences in driver behaviour between Finland and the United States of America without considering the application of TCT (Luoma, 1995). A number of studies that explored the differences between industrialised and developing countries but non of them has dealt with the application of TCT in this respect.

Some of the studies were aimed at comparing the road-user behaviour in the developing countries with that in the United Kingdom. They were part of the activities of the Transport Research Laboratory (TRL) overseas unit. Road-user behaviour at traffic signals and pedestrian crossings was evaluated in seven developing countries. The results indicated that road-users are less disciplined than in the United Kingdom. Fewer drivers chose to stop for pedestrians at uncontrolled pedestrian crossings and fewer pedestrians made use of such crossings compared with the United Kingdom crossings (Downing et al., 1991). Poor road user behaviour in some of the developing countries might be attributed to their lack of knowledge towards road safety issues. (Downing, 1991). A study made in Jamaica, Pakistan, and Thailand indicated that the lack of drivers' knowledge about some topics that are related to safety was widespread (Sayer and Downing, 1981 cited in Downing, 1991). A study on children acquiring knowledge about how they should cross the road indicated that children in developing countries received much less advice on traffic than children in United Kingdom (Downing, 1991).

Walking speeds on some pedestrian facilities were compared in a number of developing countries and compared to those in United Kingdom or the United States of America. The lowest walking speed was 65m/min in Riyadh, Saudi Arabia and the highest was 88 m/min in United Kingdom (Lam et al., 1995). Koushki and Ali (1993) have made a comparison concerning pedestrian speed in different countries. The highest speed was in the United States of America (79–88m/min) and again the lowest was in Riyadh (65m/min). This could be partly attributed to the hot weather conditions.
Driver’s non-compliance with traffic regulation in Saudi Arabia was observed. The results indicated that the problem is far greater than in urban areas in the United States of America (Koushki and Al-Ghadeer, 1992).

The experimental techniques are used in examining the cross-culture differences. Groups of participants from different traffic environments are asked to be involved in an experiment that is designed to explore their assessment and perception of traffic safety related matters. For example, the differences in risk-perception among American, Spanish, West German and Brazilian drivers were investigated. The results showed that the Spanish drivers reported the highest risk-perception, while the United States of America drivers reported the lowest (Sivak et al., 1989). As an example of the application of verbal technique in behaviour studies, drivers from nineteen European countries (six countries from Eastern European), were asked to fill in a questionnaire that was designed to measure their attitude to road traffic accidents. One result indicated that overall around 50 per cent of the drivers believe that pedestrians needs should be given more consideration when planning in the future. However, the proportion was from some former Eastern European countries. In addition, the survey indicated that there are culture differences between countries which is reflected on the drivers’ behaviour (Goldenbeld, 1998).

2.2 Accident analysis for different traffic environments: A comparative study in Sweden and Jordan

2.2.1 Background Information

The following is background information about the two countries including the traffic accident police reporting systems.

Sweden

Sweden is a Nordic country with a population of 8.85 million (1997) and an area of 449,793 km² (SCB, 1998). The population density is 20 inhabitants per square kilometre and that is one of the lowest densities in Europe. The gross national product (GNP) per capita for 1995 was 26,096 US$ (SCB, 1997).

All modes of transport are available for the movement of goods and passengers. The road network length is 210,001 km, and the number of registered vehicles in use is 3,981,000 (SCB, 1997) with an average vehicle age of 11 years. The railway network has a length of 10,939 km carrying 110 million tonnes of passengers and 55 million tonnes of goods (SCB, 1998). Cycling is a common mode of transport and almost all Swedes own a bicycle (Ekman and Draskóczy, 1989). It is widely used for short commuting trips, around 5 per cent of all travelling (in kilometres) in Sweden is made by cycling or walking (Resvaneundersökning, 1984 cited in Ekman and Draskóczy, 1989). Walking is estimated to account for two-thirds of all short travelled distances that are completed by either walking or cycling (Resvaneundersökning, 1978 cited in Ekman and Draskóczy, 1989). The estimated average annual distance travelled by each vehicle is 34,000 km

Nilsson et al. (1997) estimated the costs of traffic accidents in Sweden for the year 1995. They were nearly SEK 15 billions (1.6 US$ billion). The accident costs are estimated to compose 2.7 per cent of GNP (Elvik, 1999 cited in Jacobs et al., 2000). The statistics in 1998 have shown that 531 road-users were killed, 3,883 were seriously injured, and 17,473 were slightly injured (SCB, 2000). In term of percentages, deaths comprise 2.4 per cent of all road traffic casualties, while severe and slight injuries comprise 17.8% and 79.8% of all casualties respectively.

The police system for reporting accidents in Sweden adopts the following definitions for casualties that result from traffic accidents (OECD, 1998):

- Fatalities are those occurring within 30 days of the accident.
- Serious injuries include fracture, contusion, severe rupture, and concussion of the brain or internal injury. Also other kinds of injuries that result in hospital care.
- Slight injuries are other types of injuries not included in the serious injury definition.

Jordan

Jordan is a Middle Eastern country with 4.5 million inhabitants in 1997 and an area of 92,000 km². The population density is 45 inhabitants per square kilometre; the density is much higher in the capital Amman and the large cities like Irbid and Zarqa. Road transport is the dominant type of transport. The rural highway network length is 7,519 km, but no statistics are available for the urbanised road network. The total number of registered vehicles in 1997 was 362,811 vehicles with an average age of 15 years. The estimated average annual distance travelled by each vehicle is 32 117 km (Dar Al-Handasah, 1998). The railway network is an old narrow gauge, and is mostly used for industrial transport purposes and over short distances. Cycling is not a popular mode of transport and it is mainly used for leisure activities.

The accident cost in Jordan for 1997 is $172 million (Dar Al-Handasah, 1998), which is estimated to compose 2.5 per cent of GNP. The accident statistics in 1998 show that 612 road-users were killed, 448 were seriously injured, 4,087 moderately injured, and 12,642 were slightly injured (PSD, 1999). In terms of percentages, deaths comprised of 3.4 per cent of all road traffic casualties, while serious, moderate and slight injured road users comprised of 2.5%, 23.0% and 71.1% respectively. The definitions of casualties within the Jordanian police reporting system are as follows:

- Fatalities are those occurring within 30 days of the accident.
- Serious injuries are deep bleeding wounds or the victim had to be hospitalised. The victim has been incapacitated.
• Moderate injuries are different abrasions, bruises, swellings, and limping, but the victim has not incapacitated, even for a short while.

• Slight injuries are small visible wounds like small abrasions.

The police reporting system for road traffic accidents in Jordan are supposed to cover all accidents resulting in casualties or vehicle damage. It is by law that every road traffic casualty should be reported to the police. Insurance companies would not consider any client’s claim, unless supplemented by a police report. This practice is applicable to all accidents of differing severity. Nevertheless, not all accidents are reported, some of the property damage accidents are solved consensual on-site and the same for slight injury accidents. Unfortunately, no studies have defined the extent of under-reporting.

It should be said that the definition of traffic injuries is different in the two countries, but both of them use the same definition of fatality in traffic. To overcome the problem of different definitions of injuries in the two countries, the emphasis in the following analysis is on fatalities and if injuries are included they are considered as part of all traffic casualties without considering their severity.

To sum up, the population of Jordan is almost half of the population of Sweden and residing in an area that corresponds to one fifth of Sweden. The population density in Jordan is almost twice that of Sweden. The vehicle fleet in Jordan is relatively small if compared to that of Sweden, it composes only of one tenth of that in Sweden. Nevertheless, the average annual distance travelled by each vehicle in each country is almost the same. The road network in Jordan is only 4 per cent of that in Sweden. On the other hand, almost the same number of fatalities were reported in the two countries in the year 1996 (552 and 537 respectively). The reported numbers in 1998 dropped in Sweden to 531 while it increased in Jordan to 612. This may indicate indicates that the traffic safety situation in Jordan is worsening while improving in Sweden.
2.2.2  Trend of accident development

The general development of the traffic safety situations in the two countries is presented in Table 2.2 and Figures 2.2 and 2.3.

Table 2.2  Road traffic safety indices in Sweden and Jordan.

<table>
<thead>
<tr>
<th>Index</th>
<th>Sweden</th>
<th>Jordan</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population, 1,000</td>
<td>8,081</td>
<td>8,318</td>
<td>8,591</td>
</tr>
<tr>
<td>Vehicle, 1,000</td>
<td>2,446</td>
<td>3,077</td>
<td>3,925</td>
</tr>
<tr>
<td>Ownership (Vehicle Per 1,000 inhabitants)</td>
<td>303</td>
<td>370</td>
<td>457</td>
</tr>
<tr>
<td>Fatalities</td>
<td>1,307</td>
<td>846</td>
<td>772</td>
</tr>
<tr>
<td>Fatalities per 100,000 inhabitants</td>
<td>16.2</td>
<td>10.2</td>
<td>9</td>
</tr>
<tr>
<td>Fatalities per 100,000 Vehicle</td>
<td>53</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Fatalities inside urban areas (Percentage of all fatalities)</td>
<td>283</td>
<td>34%</td>
<td>114</td>
</tr>
</tbody>
</table>

1) J98: Data that refers to the Jordanian condition in 1998; S98: Data that refers to the Swedish condition in 1998.

Figures presented in Table 2.2 were chosen to reflect the development of traffic safety conditions over 28 years. This is due to the fact that the data available in Jordan was for the period (1970-1998) while in Sweden for (1950-1998).

According to Table 2.2, the number of vehicles is increasing with time, but the increase is not as sharp in Sweden. A steady increase was noticed for the first twenty years with an average rate of 2% and during 1990-1998, it was 1.1%. On the other hand, in Jordan, the increase was sharp during the seventies with an average rate of 20%; then it began to drop in the eighties. In the late eighties recession the average rate of increase in the number of vehicles did not exceed 8% and it was almost 6.5% during nineties.

Population growth rate in Sweden is almost constant with an average of 0.3% per year. In Jordan, the population growth rate was as high as 5% per year during seventies and eighties and then slightly declined to 4.7% per year in the nineties.

Change in fatality numbers over the period 1950-1998 for Sweden and over the period 1970-1998 in Jordan is presented in Figure 2.2.1. The change in fatality rates (fatalities per 100,000 inhabitants) for the two countries over time are presented in Figure 2.2.2.
Figure 2.2.1 Change in fatality numbers over time (SCB, 2000; PSD, 1999).

Figure 2.2.2 Change of fatality rate over time expressed by fatalities per 100,000 inhabitants (SCB, 2000; PSD, 1999).

The number of fatalities in Sweden continued to increase until 1967 when driving was changed from left to right. It continued to rise over the three years following this switch. It began to decline until the mid-eighties when it rose slightly. Since the beginning of the nineties the number of fatalities has reduced, with minor exceptions, every year. The fatality rate in Figure 2.2.2 follows the same trend. Accident statistics in Jordan show that the number of fatalities fluctuates from one year to another, but the general trend suggests that the number of fatalities increase with time. There is only one significant drop in the fatalities in the year 1986. It could be attributed to the introduction of a new traffic legislation. Around 400,000 Jordanians came back to Jordan from Kuwait because of the Gulf War. The number of fatalities increased, as this group of ex-patriots
was not familiar with the traffic environment or regulations. Another contributory factor could be the introduction of a new regulation in the early nineties that allow 18 years old Jordanians to rent a car.

According to Table 2.2 the fatality rate per capita in Jordan is twice as high as the rate in Sweden. This was based on 1998 statistics, which implied that the Jordanians are subjected to twice the risk that of the Swedes. Figure 2.2.2 shows that the fatality rate in Sweden and Jordan were close to each other in the early seventies, but have diverged drastically between 1975-1985. The rates became close to each other again until 1990 when they diverge again.

The mobility in traffic expressed as the vehicle ownership level and its relation to fatalities provides another dimension to the traffic safety problem by viewing it as transport problem. Figures 2.3.1 and 2.3.2 show the trend in fatality rate expressed by fatalities per 100,000 vehicles over the period 1950-1998 for Sweden and the trend in fatality rate for the period 1970-1998 for Jordan. Figures 2.3.1 and 2.3.2 also show the development of vehicle ownership level expressed as number of vehicles per 1,000 inhabitants for the two countries.
Figure 2.3.1  Fatalities per 100,000 vehicles and vehicles ownership level in Sweden for the period 1950-1998 (Vägverket, 1998; SCB, 2000).

Figure 2.3.2  Fatalities per 100,000 vehicles and vehicles ownership level in Jordan for the period 1970-1998 (PSD, 1999).

Figure 2.3.1 indicates that vehicle ownership level in Sweden was increasing rapidly during the sixties and seventies. The rate gradually levelled off in the eighties and during the last years of the investigated period it has been almost constant. The fatality rate has always been declining; while the fatality number that are presented in Figure 2.2.1 were increasing until the early seventies when they then started to drop. The general trend that is indicated in Figure 2.3.1 is in agreement with Oppe's hypothesis regarding the degree of motorization and its relation to the fatality (Oppe, 1989).

Figure 2.3.2 shows that fatality rate in Jordan is decreasing. However, the last part of the curve shows a slight increase in the fatality rate, which could be attributed to the reasons
stated above. The vehicle ownership level begins to slowly increase in the late eighties to the mid-nineties when it started to decrease. Nevertheless, it should be noted that during 1991-1995 there were a number of vehicles that entered the country after the Gulf War but were not registered. The vehicle ownership was actually growing but many vehicles were not registered. Hence, Figure 2.3.2 supported Oppe’s hypothesis by stating that as vehicle ownership level increases, the fatality rate decreases. It is similar to the general trend in the industrialised countries where the fatalities have dropped as the degree of motorization has grown. However, it should be pointed out that the fatality rate in Jordan is twelve times that in Sweden. This means that the situation is very serious in Jordan and considerable effort is needed to reduce its severity.

Table 2.2 highlights a phenomenon with regard to fatal accident location. In Sweden more than two-thirds of all road traffic fatalities in 1998 occur outside urban areas. The corresponding proportion in Jordan is less than one third. This proportion of fatalities in Sweden is maybe because the driving speed outside urban areas is usually high. The high proportion of fatalities inside urban areas in Jordan is maybe because of the high exposure in these areas. Big cities in Jordan are densely populated and most of the kilometres travelled are inside cities. Only a small fraction is travelled outside urban areas.
2.2.3 Fatalities by road-user type

The distribution of all road fatalities reported in Sweden during 1994-1998 by road user type is shown in Figure 2.4.1. Figure 2.4.2 presents the distribution of all road fatalities reported in Jordan during 1994-1998 by road user type.

Figure 2.4.1 Swedish police reported fatalities by road-user type for the period 1994-1997 (Vägverket, 1998, SIKA, 2000).

Figure 2.4.2 Jordan police reported fatalities by road-user type for the period 1994-1998 (PSD, 1998, 1999).

The available accident statistics in Jordan make no distinction between vehicle passenger fatalities or vehicle drivers’ fatalities. Only pedestrian fatalities are separated from all road traffic fatalities. Cyclists are few in numbers and included in pedestrian fatalities. In Sweden, there is a clear distinction between different road-user types, i.e. drivers,
passengers, pedestrians, and cyclists. For comparison purposes a decision was made to include both the drivers' and passengers' fatalities under the car-occupant category.

Figure 2.4.1 shows that pedestrian fatalities in Sweden account for almost one-sixth of all fatalities. Cyclist fatalities make up one tenth, and vehicle fatalities two thirds of all fatalities. In Jordan, the proportion of accidents that involve pedestrians has declined from 17.7% in 1994 to 13.8% in 1998 (PSD, 1998). Still their share of fatalities has risen from 40 to 46% (Figure 2.4.2). Pedestrian fatalities are three times higher in Jordan than in Sweden.

### 2.2.4 Pedestrian Casualties.

Most of pedestrian accidents that resulted in fatalities in Jordan were reported inside urban areas. This accounted for 84 per cent of accidents in 1998 (PSD, 1999). In Sweden 62 per cent of pedestrian fatalities were reported in urban areas (SIKA, 2000). There are no statistics in Jordan about pedestrians’ travelled distances. It is expected to be high. Poor public transport systems and the low vehicle ownership level make walking an appealing alternative to commute. Urban planners have not handled the increase in demand for walking in Jordan. The pavements are poorly maintained, if they are provided, and pedestrian facilities for crossing are not always available. In addition, the present system has been designed to encourage high speed for vehicle traffic.

Pedestrian casualties by road speed limits for both countries are presented in Figure 2.5. Data from Sweden includes injuries and fatalities while the data for Jordan includes fatalities only. Figure 2.5 indicates that 75 percent of all pedestrian casualties in Sweden took place on roads with a speed limit of 50km/h. Forty-one per cent of fatalities in Jordan took place on roads with a speed limit more than 50km/h.

![Pedestrian Casualties by Road Speed Limit](image)

**Figure 2.5** Pedestrian casualties by posted road speed limit (km/h). Data for Sweden is for injuries and fatalities while data for Jordan is only for fatalities (SIKA, 2000; PSD, 1999).
The pedestrian casualties (fatalities and injuries) by age groups are shown in Figures 2.6.1 and 2.6.2 (expressed as their proportion to the population of each age group). It should be noted that the two countries adopt different categories for age groups as shown in Figure 2.6.1/2.

**Figure 2.6.1** Pedestrian casualty rate by age group for 1998 accident statistics in Sweden (SCB, 2000; SIKA, 2000).

**Figure 2.6.2** Pedestrian casualty rate by age group for 1998 accident statistics in Jordan (PDS, 2000).
Figure 2.6.2 clearly illustrates that pedestrians of all age groups in Jordan are subjected to a high risk of being killed in traffic compared to pedestrians in Sweden (Figure 2.6.1). According to Figures 2.6.1/2, children under the age of 6 years have a low risk of being killed in traffic in Sweden while they are at a high risk in Jordan. In both countries, the elderly pedestrians are subjected to the highest risk of being killed in traffic compared to other age groups.

Concerning the risk of being injured in traffic, the pedestrians in Jordan are also subjected to higher risk than in Sweden. Children in Jordan have the highest risk. The age group 15-19 has the highest risk in Sweden. Elderly pedestrians in both countries are subjected to high risk of being injured in traffic, though not the highest.

**Conclusions**

- The literature review indicates that there is a difference in traffic safety conditions between different countries, a difference that cannot only be attributed to the differences in traffic environments.

- The international differences in traffic environments have been more extensively explored for industrialised countries. Few studies have been carried out to investigate the differences between developing and industrialised countries.

- Accident analysis is more frequently used than behavioural studies when exploring the differences in traffic safety conditions between countries. Behavioural studies need close co-operation between researchers from different countries and sufficient resources, which are not always available. Consequently, these studies are usually limited in number and characterised by limited scope.

- The use of the Traffic conflicts technique as one type of the behavioural study has received considerable attention as a tool to investigate the cross-cultural differences between industrialised countries. Literature reviewed in this study indicated that it has not been used to explore differences in road-users’ behaviour between developing and industrialised countries.

- As expected, accident statistics in Sweden and Jordan indicated that the traffic safety conditions in Jordan are inferior. Fatality rate (fatalities per 100,000 inhabitants) is twelve times higher in Sweden while the vehicle ownership level in Jordan is only one sixth of that in Sweden. The pedestrian problem is more serious in Jordan. Pedestrian fatalities in Jordan are around 46% of traffic fatalities in 1998 compared to 13% in Sweden. Children and elderly pedestrians in Jordan are the most vulnerable to be injured or killed in traffic when compared to similar age groups in Sweden.
3 The Swedish Traffic Conflicts Technique

3.1 The present Swedish TCT

3.1.1 The definition of conflicts - Basic concepts

The basic idea behind the development of the Swedish conflict technique is that road-users interact in traffic. Their interactions can be described as a continuum of events that occur with different probability and different degrees of seriousness, which can be visualised as a pyramid. It is often called a safety pyramid as shown in Figure 3.1 (Hydén 1987). At the top of the pyramid are accidents the most undesirable events that no road-users would like to be involved in. Further down are the less severe events that are categorised as conflicts, either slight or serious. At the very bottom of the pyramid, are the undisturbed passages. Serious conflicts according to Hydén (1987) can be characterised as a breakdown in the interaction between the road-users that reflects an accident potential that is high enough that at least one of the road-users would not like to be involved in voluntarily.

![Figure 3.1 The safety pyramid (Hydén, 1987).](image)

In order to differentiate serious conflicts from the rest of events in the continuum. A time-based measure was selected. It was preferred than other criteria that were considered as distance based or deceleration power based measures (Hydén, 1987). Despite this effort to define what serious conflicts are, the safety pyramid is believed to be hypothetical. It was not put into practice to a degree that makes it possible to distinguish between different traffic conditions in different environments. The shape of the safety pyramid forms the essence of the work of Svensson (1998) who investigated how the shape of the pyramid could be used in describing and evaluating the safety conditions at transport units that reflects different environments. Svensson (1998) introduced the concept of a severity hierarchy that is supposed to describe events in traffic of different severity; at the top of the hierarchy are the injury accidents. The hierarchy depends on the type of junction under study and manoeuvres under consideration.
The time-based measure used to define the serious conflicts in the Swedish TCT is primarily based on the TTC concept. The TTC is the hypothetical time for conflicting vehicles to collide if their speed and direction had not been altered (Figure 3.2). This was first introduced by Hayward (Hayward (1972, cited in Hydén, 1987). A modification to the TTC definition was presented by Hydén. He introduced the time to accident (TA) notion. It represents one point in Hayward’s time to collision (TTC) graph when one of the road users starts an evasive action as shown in Figure 3.2. The TA-value that was used in determining the conflict severity is defined as follows (Hydén, 1977).

Time to accident is the time that remains to an accident at the moment when evasive action has just been started, presupposed that the had road-users continued with unchanged speeds and directions.

**Figure 3.2** A time to collision (TTC) graph illustrating TA and MTTC (Hydén, 1987).

The threshold that differentiates between serious and slight conflicts in the original technique was defined as follows *A serious conflict occurs when the time to accident (TA) is equal to or less than 1.5 seconds*”. The TA-value was estimated for the road-user who took evasive action. If both road-users took evasive actions, the TA-value of the road-user who took the evasive action earlier determines the conflict severity. The road-user who has the highest TA was considered as the relevant road-user (RRU). The relevant road-user is believed to control the situation because she/he has the greatest time margin to perform her/his action.

The 1.5 seconds threshold seemed to work satisfactorily in urban areas where the speed on average is rather low; but not in rural areas where the speeds is higher. Linderholm (1981 cited in 1992) stressed the need to establishing the definition of conflicts by considering the speed of the involved road-users and the TA-values. Linderholm investigated the relation between the TA-values and the conflicting speed as a function of
the type of evasive action undertaken, i.e. TA-speed graph for a braking evasive action is different from the TA-speed graph for a swerving action.

In the present Swedish TCT, the TA-speed graph is used to define the conflict severity as shown below. The speed on the TA-speed graph will referred to the conflicting speed. It is defined as the speed of the road-user taking evasive action, for whom the TA-value is estimated, at the moment just prior to the start of the evasive action.

Gårder first suggested the conflict definition that based on TA-speed graph: "A serious conflict takes place when two road-users are involved in a conflict and a collision would have happened with the sum of 0.5 seconds and the braking time for heavy braking on slightly damp pavement"; see (Figure 3.3) (Gårder, 1982 cited in Linderholm, 1992). The braking distance, that was used to estimate the TA-value is inversely proportional to the square of the speed (the higher the speed the lower the TA-value).

![Figure 3.3](image)

**Figure 3.3** The threshold that differentiates serious conflicts from non-serious conflicts (Gårder 1982).

Two modified versions of Gårder’s definition were among the five alternative definitions (Figure 3.4) that Hydén (1987) investigated when he arrived at what he called “the modified definition”. It was altered to the present definition of serious conflicts. Hydén (1987) based on a number of accidents that were investigated in-depth; he estimated their TA-speed and utilised them in investigating the third alternative definition. A fourth alternative definition was the original definition of serious conflict (1.5 seconds threshold). The last definition was based only on conflicting speed. A presentation of the five alternative definitions is shown in Figure 3.4.

Two basic concepts were introduced when comparing the five alternative definitions of conflict based on the so called the “process validity concept”. The following concepts were considered:
Uniform severity level is defined based on some theoretical threshold that is used to differentiate serious conflicts from the non-serious conflicts. For example, the TA-value of 1.5-seconds "the original technique" is a uniform severity level and TA-value of 1 second is the other.

Uniform severity zones (Severity zones); are defined as the area that is confined between two uniform severity levels. For example, all conflicts that have at least TA-value of 0.5 seconds and at most 1.0 second have the same severity zone, assuming they were defined according to the original definition of conflicts.

![Diagram](image)

**Figure 3.4** The five different alternative definitions preliminary threshold levels. (No safety margin is included in the presentation "Gårder earlier suggested 0.5 seconds")

The modified version of the serious conflict definition proposed by Hydén (1987) was

"A serious conflict is an event where the time to accident and conflicting speed for the relevant road-users produces a combined value that lies in severity zone 3, shown in Figure 3.5, or higher for the 2nd alternative definition".

This definition is basically Gårder’s but Hydén (1987) increased the safety margin from 0.5 seconds to 1.0 second. However, the present definition reverted back to Gårder’s safety margin of 0.5 seconds.

The RRU in the present definition of Swedish conflict was altered from the original definition to:

The road-user that took evasive action and his combined conflicting speed and time remaining to accident produced the least severe conflict.
Figure 3.5 Alternative definition 2nd and the original definition of serious conflicts (Hydén, 1987).

Classifying the conflicts in different severity zones on the TA-speed graph produces a conflict distribution that reflects the traffic safety condition for the transport entity under investigation (Svensson, 1998). Moving from severity zone one to twelve is moving towards the more severe situations and is similar to moving up to the top of Hydén’s pyramid. Svensson (1998) investigated the possible shapes of the pyramids as function of junction type and road user manoeuvre. In her work, she used the term safety hierarchy to describe the interactions between road-users in the traffic process. This can be represented in different shapes depending on junction types or manoeuvres. To construct the hierarchy there is a need to transfer the concept from being abstract into measurable parameters based on certain presumptions. This would result in producing the severity hierarchy that could be used for the analyses of the traffic safety process. The shape of the hierarchy is believed to reflect the level of safety of the investigated transport entity. According to Svensson it is not only the critical events such as serious conflicts that determine the safety conditions, it is also the shape of the hierarchy that provides information about the existing level of safety (Svensson, 1998).

3.1.2 The operational use of the concept

To put the technique into practice, particularly at the first stages of the technique’s development, the main concern was about detecting and rating serious conflicts. The technique had to be simple to be popular among users. By weighing the advantages and the disadvantages of using video or on-site observers, after ruling out the use of film, it was concluded that on-site observation is the most viable technique to record conflicts.
However, the use of video was recommended for training purposes. The use of an objective or semi-objective technique was strongly considered in the early nineties. It is based on analysing events collected from videotapes and it is currently used for research purposes only. It is envisaged not to deploy human observers on site conflict detection, but to use video camera instead. Further, the fully automated technique is under development and is not operational yet (Odelid and Svensson, 1993; Andersson and Odelid, 1997; Andersson, 1999).

Observers are usually trained for five days before carrying out field observations. The very basic assumption for training the observers is that all road-users are continuously making some estimation of time margin as part of their normal behaviour in traffic. They make the needed adjustments of their speeds or directions of travel due to their estimation of this margin. The observers are trained to estimate the TA-value and the speed of the involved road-users immediately before the conflict happens.

Traffic conflict studies are normally conducted at junctions of any type but they could also be made at non-junction areas (road links), although this is difficult, as it is time consuming. This is because conflicts seldom occur and longer observation periods are needed. Conflict studies are always planned to complement accident studies. Preceding conflict studies by analysing accident data is of great help to the observers because it leads them on where conflicts are expected. On the other hand, it might introduce bias because of this prior knowledge. The observers might record more conflicts on the part of the junction that has a high accident record.

Conflict observations are preferably made in daylight and in good weather conditions. This is a limitation of the technique that is imposed due to the use of human observers in conflict detection. Besides it is a necessity to ensure that the conditions are comparable in “before and after” studies. The observation periods should be long enough to provide a sufficient number of conflicts but not too long as to influence the observer performance. Many factors might influence the length of the observation period as traffic volume, and the complexity of the site. However, a period of thirty hours of observations is considered to be sufficient. It may be shorter or longer depending on the site conditions (Hydén and Draskóczy, 1991).

One or two observers score conflicts at each arm of a signalised junction or at both arms of the priority road of a non-signalised junction. Their location on a junction should be a function of the speed limit on the site; the higher the speed the further they should be from site. If video taping is considered the camera should be located high up to secure an overview of the area that influences.

The observers are required to record information as soon as one of the conflict participants commences an evasive action. The estimated speed of each conflict participant at the moment when one of them undertake an evasive action is scored. The estimated distance of each participant from the potential collision point at that time is also recorded. Other supplementary data that is expected to provide better understanding of the conflict process may be added.
3.1.3 Reliability and validity

The reliability and validity of TCT are the two main issues often discussed when any TCT technique is to put into practice. The reliability and validity are synonymous to what is often called internal and external validity of TCT, which is defined as follows:

- The reliability of the technique (internal validity) measures to what extent conflicts can be detected in accordance with the theoretical definition. The theoretical definition of conflict severity in the Swedish TCT is determined by collecting information on the speed and the TA-value.

- The validity (external validity) measures to what extent conflicts (serious conflicts in the Swedish TCT) could be used in describing what they are intended to describe, which is the safety of the entity studied.

Reliability

The reliability of observers is normally tested as internal or external reliability (Hydén and Draskóczy, 1991). The internal reliability is tested by considering the inter-observer and intra-observer reliability. The inter-observer reliability measures the agreement between different observers in detecting the conflicts. While developing the Swedish TCT the inter-observer reliability was tested twice. After five days of training, the results show that 86% to 90% of all serious conflicts were correctly recognised (Hydén, 1977). The external reliability of observers measures how they estimate the speed and TA-value compared to objective measures of these conflict parameters. Hydén investigated this while validating the Swedish TCT. He based his analysis on data collected from the "Malmö calibration study" (Grayson, 1984). He used data obtained from the semi-objective technique developed in the Netherlands. Hydén showed that observers failed to score 26% of the conflicts that should have been scored (Hydén, 1987). He demonstrated that the average TA values estimated by Swedish observers showed a difference of 0.05 seconds from the objective TA values. In half of all analysed conflicts the observers' estimations of TA-values were within 0.2 seconds of the objectively evaluated value. The average estimated speeds were lower than the objective speed by 3km/h (Hydén, 1987). These results indicate that the Swedish observers are reliable in detecting, and in scoring the conflict parameters (TA value and speed).

Validity

Traditionally, the validity issue was a measure of TCT’s ability to predict accidents or the average expected number of accidents as proposed by Hauer and Gårder (1986). This kind of validity is commonly known as product validity. Hydén (1987) investigated the product validity of the technique, but he also introduced a new concept of validity and that is the "process validity". Process validity is a measure of the similarity in the process that leads to accidents or leads to conflicts.
Product validity

A large validation study of the Swedish TCT was carried out at 115 junctions in two Swedish cities, Stockholm and Malmö, in the 1970's. Three data sets from 115 junctions were obtained. A model for conversion between serious conflicts and injury accidents ($\pi$) was produced for each data set. The models were developed by considered the road-user category and traffic class (which is determined based on the junction type and the manoeuvre type). The model was developed based on the assumption that both conflicts and accidents follow the Poisson distribution. To equate the conditions of accident periods with the time of the conflict observation, the conversion factors were corrected for the difference in traffic volume between the two periods. The estimated conversion factors for the three data sets were similar to the degree that they were combined. This was a good indication about the stability of conversion factors from one city to another in Sweden. The conclusion was that it was possible to use the technique. Linderholm (1981, cited in Linderholm, 1992) revised these conversion factors by considering the change in accident numbers with time in order to have comparable conditions between the accident periods with the time of the conflict observation (Table 3.1).

**Table 3.1** Accident to conflict conversion factors developed by Linderholm.

| Conflict | Situation | Car-Car // | Car-Car ⊥ | Car-pedestrian
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity class 1</td>
<td>Speed ≤ 35 km/h</td>
<td>0</td>
<td>2.4</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>1.0 ≤ TA ≤ 1.5 sec</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity class 1</td>
<td>Other conflicts</td>
<td>2.8</td>
<td>11.9</td>
<td>33.9</td>
</tr>
<tr>
<td></td>
<td>Where TA ≤ 1.5 sec</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All value should be multiplied by $10^{0.5}$ (Linderholm, 1992).

Svensson (1992 cited in Linderholm, 1992) applied Hauer and Gårder (1986) approach during her work in validating the Swedish TCT. She concluded that three days of conflict studies give a better estimate of the future accident frequency of an intersection than a three years of accident history.

Process validity

Adopting the process validity concept completed the validation of the modified definition of serious conflict in the Swedish TCT. Hydén (1987) compared the last phases of the process that lead to accidents to the process that lead to serious conflicts. Police accident files were investigated to collect as much information as possible to facilitate such a comparison. The comparison between conflicts and accidents was based on TA values, speeds of the involved road-users just when the actions were performed, and the type of
evasive actions.

Hydén (1987) plotted the TA-value versus the conflicting speed for both conflicts and accidents and for each type of accident (vehicle-vehicle; vehicle-bicycle, vehicle-pedestrian). The distributions of accidents and conflicts were examined and the main conclusion was that the pattern noted in all graphs seemed to be similar. However, the accidents are located more to the left of the graph and the TA-values for accident data were lower. Regression lines that relate the conflicting speed to the TA-values were developed for all types of conflicts and accidents were similar in their inclinations.

The type of evasive action made in both accidents and conflicts was studied. According to the results presented in Table 3.2 braking was by far the most common type of evasive action in both accidents and conflicts but with different proportions. It is more frequent in conflict data than in accident data. Braking and swerving combined was the second most common for both conflicts and accidents. It is more common in accidents and this is be justified by saying that in accident situations the involved road-users might do whatever they can to reduce the consequences of the accidents. Acceleration was rarest type of evasive action in either accidents or conflicts. The overall conclusion was that the similarity between accident and conflict in this context (i.e. type of evasive action made) is satisfactory. The RRU issue was evaluated for both conflict and accident data and there were similarity between conflicts and accidents.

**Table 3.2** The proportion of evasive actions recorded in the investigated accident and conflict data as part of the process validity analysis (Hydén, 1987).

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Braking (%)</th>
<th>Swerving (%)</th>
<th>Acceleration (%)</th>
<th>Braking and swerving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>68</td>
<td>10</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Conflicts</td>
<td>79</td>
<td>5</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

The main conclusion drawn was that there are many similarities between serious conflicts and accidents. Thus, conflicts could be used as a complement or even substitute accidents.

### 3.2 The Use of the present Swedish TCT

The application of the present Swedish TCT has proved to be a useful tool for safety evaluation at national and international levels. It has been applied in many countries during the last two decades. However, the reported applications were for research purposes. It has not been applied as part of routine work by local road authorities except for in Göteborg. It is the second largest city in Sweden, which implemented the technique on a larger scale within its own organisation. The technique application was limited because of costs and that may be mainly due to the deployment of observers.
Chapter Three

The Swedish TCT was applied in Sweden in connection to pedestrian safety problems in a number of studies (Draskóczy, 1990; Hydén & Draskóczy, 1991). Towliat and Ekman (1995) used the technique for studying a pre-marked area at pedestrian crossings used as a pedestrian safety measure in Stockholm. At an international level, the Swedish traffic conflicts technique was used in Drive I and II projects for measuring the effectiveness of introducing new techniques for vulnerable road-user detection in a number of European countries (Ekman and Draskóczy (eds.) 1992; Carsten 1995). In all the technique applications performed well with relatively reasonable cost, even, at sites where it has never been used before as motorways (Svensson and Várhelyi, 1995).

Theoretically, the technique is well established in the sense that it can handle different situations with a sound background. In Malmö’s calibration study, the Swedish technique was compared with a number of conflict techniques developed in other countries. The Swedish TCT incorporates the three variables that were found to be important in explaining the severity of conflict. Two of these variables, namely time measure and conflict type (i.e. vehicle-vehicle, vehicle-pedestrian), are directly included within the technique while the distance is indirectly included through the TA-speed graph (Hydén, 1987).

3.3 Problems identified with the present Swedish TCT

The wide use of the TCT does not exclude the fact that building up the experience means facing new problems. It is not always that new problems are expected to appear during the practice of the technique, but rather the challenge of facing drawbacks that were built into the tool itself. The real issue is to try to eliminate or minimise the influence these problems on the performance of the technique.

3.3.1 Pedestrian conflicts - Relevant road-user (RRU)

Conflict definition according to the Swedish TCT seems to treat the driver as the RRU, not the pedestrian. According to the present definition of serious conflicts in the Swedish TCT once the pedestrian takes evasive action, and she/he is the RRU, most of the situations appear less severe than they might be. The reasons to explain this phenomenon are given below.

Firstly, in vehicle-pedestrian conflicts in Sweden usually the driver performs an evasive action to avoid the consequences of being involved in conflicts and not the pedestrian. One of Hydén’s findings (1987) provided a support for such an argument, as the pedestrians were the RRU in only 13% of all investigated vehicle-pedestrian conflicts. Besides, it is easier to detect the driver’s action and not the pedestrian. When the vehicle brakes it is obvious but, if a pedestrian is walking and stops it might appear that he did it as part of his or her earlier planned course of action. Accordingly, it is expected that observers would tend to consider the driver as RRU more frequently than pedestrian. They are not used to conflicts where pedestrians take evasive action. When they are confronted with such situations, they might have problems in detecting them precisely. Furthermore, there is a problem in assessing the distance to the potential point of collision. This is not an easy task for the observer to perform since he is expected both to
estimate the distance to the potential collision point for the two road-users and their speed. The difficulty that faces the observer is higher when an assessment is needed for a fast vehicle that is in a distance away from the potential collision point and for a pedestrian at a distance away from the same point. It might be difficult for the observer to track the trajectory of both road-users to the potential collision point. It is easier for the observer to estimate the lower speed for the road-user who is not far from the potential collision point. However, it still a problem for the conflict observer to estimate a very short distance to the potential collision point, particularly if the observations are made by using video-tapes and if a pedestrian is the involved road-users.

Secondly, even if the detection is perfectly conducted, the problem is still not solved. The border-line - “threshold level” - that is supposed to discriminate the serious from non-serious situations was developed for all types of conflicts regardless of the type of the involved road-user. Initially, Hydén’s findings indicated that the threshold for vehicle-vehicle conflicts was not the same as for vehicle-pedestrian conflicts (Hydén, 1987). He concluded by suggesting that only one threshold should be used to define the severity for all conflict types. However, it is believed that pedestrian-vehicle conflicts are different from vehicle-vehicle conflicts in terms of speed and ability to perform evasive action. If the RRU is a pedestrian, she/he could stop suddenly without the need for a long stopping distance. Almost every pedestrian could stop suddenly while vehicles are not equipped with the same capability for stopping, although some vehicles’ braking systems are more effective than others. Using the same threshold for vehicle-pedestrian conflicts as that for vehicle-vehicle conflicts in the last 15 years indicated that vehicle-pedestrian conflicts, which involved pedestrians as RRU’s appeared to be non-serious. Towliat and Ekman (1995), while evaluating the effectiveness of introducing a pre-marking area at pedestrian crossings in Stockholm, produced a conflict distribution that shows a cluster of conflicts that accumulated underneath the threshold level as shown in Figure 3.6. This cluster actually includes vehicle-pedestrian conflicts where the pedestrian is the RRU.

![Figure 3.6](image-url) Conflict severity distribution at a zebra crossing in Stockholm (Towliat and Ekman 1995).
The data presented in Figure 3.6 might be used as a basis to formulate a hypothesis that states that when the pedestrian in car-pedestrian conflicts takes evasive action then it is most probable that these conflicts would not be serious ones. Let's take an example why such thing can happen.

Suppose that there is a pedestrian crossing the street at a speed of 5 km/h (1.4 m/sec). At the same time there is a vehicle approaching the crossing at a speed of 40 km/h (11.11 m/sec). The distance that separates them from the potential collision point is 1 m and 8 m receptively (Figure 3.7). Both of them have a TA-value of 0.7 seconds. Now if both perform evasive actions, then the pedestrian is considered the RRU, because his combined speed and TA-value is located in severity zone 4, while it is in severity zone 8 for the vehicle driver (Figure 3.5). Let’s assume that vehicle driver speed is 20 km/h with a TA-value of 0.7 seconds. The severity zone for the vehicle driver based on her/his speed and TA-value is 6 if she/he has reacted. If the pedestrian crossing at the same speed, as before, and he is 1.0 m away from the potential collision point makes an evasive action, then the conflict severity would be located in severity zone 4 (Figure 3.5). Thus, regardless of the speed of the vehicle or how far it is from the potential collision point, the same severity of the conflict is recorded had the pedestrian taken evasive action. As long as the pedestrian acted evasively, the two situations would be considered identical (i.e. non-serious "slight" ones).

![Diagram](image)

**Figure 3.7** A hypothetical situation for pedestrian-car conflicts.

To elaborate on this it is possible to include, in the comparison, other vehicle speeds and alternative pedestrian distances to the potential collision point than the previous listed one. Table 3.3 demonstrates how the distance of a vehicle to the potential collision point could be related to conflict severity if the driver performs evasive action for three predetermined speeds, 20, 40, and 60 km/h.
Table 3.3  The influence of road-user distance to the potential collision point on conflict severity evaluated at three vehicle and one pedestrian speeds.

<table>
<thead>
<tr>
<th>Vehicle speed 20km/h</th>
<th>Vehicle speed 40km/h</th>
<th>Vehicle speed 60km/h</th>
<th>Pedestrian speed 5km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_d (m)</td>
<td>T_A-value (sec)</td>
<td>Severity zone</td>
<td>V_d (m)</td>
</tr>
<tr>
<td>15</td>
<td>2.70</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>12</td>
<td>2.16</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>1.80</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>1.44</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>1.08</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>0.90</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>0.72</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>0.54</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>0.36</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>0.18</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>0.5</td>
<td>0.09</td>
<td>8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Shaded areas: areas refer to non-serious conflicts, V_d and P_d definitions are presented in Figure 3.7.

Table 3.3 also shows the relation between pedestrian distance to the potential collision point and the severity of conflict, if he or she takes evasive action, assuming that he or she is walking at 5km/h. The results in Table 3.2 indicate that if the driver is at a distance of at furthest 5, 18, 37 m from the potential collision point and driver using a speed of 20, 40, and 60 km/h respectively then they maybe involved in a serious conflict. If the pedestrian takes evasive action, he or she should not be further away from the potential collision point than 0.75m to be involved in a serious conflict, otherwise the situation would be non-serious. Therefore, the observers need to be alert in assessing the pedestrian distance to define a serious conflict. Such level of alertness is not needed if the driver acted evasively. The distances are relatively longer and lower accuracy level is needed to estimate such distances.

Accordingly, it is expected that some vehicle-pedestrian conflicts to be considered non-serious, although they are not, simply because observers misJudged the distances. This is most likely to happen in complex situations and the distances are not clear. This problem could be avoided in the future if the detection and evaluation of conflicts are done using an automatic procedure.

3.3.2  On-site observations versus automatic detection

The use of human observers to collect field data was considered to simplify the application of the technique. They were chosen because it was believed that the use of an objective technique, based on using videotapes for recording and tedious computer work for analysis, would make the practitioners reluctant to use the technique. However, when the technique was put into practice, there were limitations because it utilised only human
observers for conflict detection and recording. These limitations are summarised as follows:

- The field observations are normally conducted in daylight in good weather conditions, and over a relatively short period. The representation of observations collected in such conditions for night-time or poor weather is questionable.

- Collecting enough conflict data, particularly at sites with low traffic volumes, means that the observers need to spend a long time on site. This makes the technique more expensive to be applied in such areas.

- The use of human observers is expected to induce a subjective element in detecting and rating the severity of conflicts. Training is needed for the observers before they are asked to carry out field observations. Their reliability should always be evaluated in order to make sure that they collect information in a consistent manner.

- The observers are expected to face problems when they have to collect a large numbers of information on site. This would also reflect on the quality of such data. In addition, extra burden is put on the observer if more information is needed. Some type of information might not be easily collected by human observers on-site. The observer might even have to review the same event more than once before being able to collect the required information and this is only possible if the events are videotaped or filmed. Svensson (1998) used video recording to collect vehicle-pedestrian interactions; interactions are frequent in number, which makes it extremely difficult to collect them directly on site.

To overcome these limitations, the use of image processing techniques provides an automatic detection facility of conflicts. The observers are not needed for long periods of time on-site, and data could be collected during day and night-time. This solves issue of representation.

3.3.3 Omission of events preceding conflicts

The result of the process validity study introduced by Hydén (1987) showed that there are similarities between conflicts and accidents in their last phases. What is meant by last phase is the conflict or accident characteristics, such as the speed and distance or TA-values, type of evasive action and type of road-user involved. Hydén (1987) also raised the issue that not only the last part of conflicts is of interest, any event or behaviour that precedes the conflict might add to the knowledge about conflict or accidents. The process of validity concept introduced by Hydén was based on limited number of accident and conflict characteristics. Lack of available information hindered Hydén from including other characteristics that describe the last phase of conflict or even the events that preceded the conflicts (Hydén, 1987). It is believed that other information, apart from those tested by Hydén (1987), that describe the conflict process are expected to provide a deeper insight in conflict mechanism.
In the same way as accidents, the conflict process could be divided into three phases, pre-event, event (conflict) and post-event (Haddon matrix, 1980 cited in Andersson and Menckel, 1995). There are a number of conflict characteristics that are associated with each phase, which might influence the relation between conflicts and accidents. If it is possible to combine the information about pre-conflict with those during and after conflict, then the conflict could be seen as a dynamic situation. In other words, conflict is described as a life event that starts, endures and ends. This kind of analysis requires collecting a great deal of information that depicts conflict as a dynamic situation. Information collected in the present Swedish TCT describes the type of road-user, manoeuvre type, and conflict characteristics and some other descriptive statements that are supposed to reflect the observer perception of the event in hand. What are collected so far are some aspects of the pre-conflict phase and the conflict phase that determine the severity of the conflicts. They provide only very limited information that describes some dynamic characteristics of conflicts, such as the speed and the distance to collision points. Although these characteristics have a dynamic nature, they are not enough to provide an overview of the whole mechanism of conflicts.

Malaterre and Muhlrad (1977) were the first to introduce the so-called severity index that attempts to weigh the conflict according to some of its characteristics. They were aimed to consider all conflict characteristics in one dimension, which could be considered as one approach of studying the conflict mechanism. Malaterre and Muhlrad (1977) calculated the severity of a conflict as a multiplication of coefficients that stand for the urgency of the action, speed of the fastest road-user, type of road-user involved and the angle of collision. The sum of conflict severity index is the so-called site risk-value, this value is correlated with the corresponding number of injury accidents. Malaterre and Muhlrad (1977) based their work on a limited number of factors that they considered in their calculation of conflict severity. Nevertheless, their work provides a good basis for further development, which could include other approaches to handling the dynamic vision of conflicts.

To conclude, it seems that the inclusion of other dimensions depicting the dynamic mechanism of conflicts would be an enhancement to the present definition of Swedish TCT.

3.3.4 Application of Swedish TCT in different countries

The Swedish Traffic conflicts technique, was used applied without any modification in other countries except in Finland. The technique in Finland was a modified version of the original Swedish traffic conflicts technique (Kulmalä, 1982 and 1984).

The Swedish TCT has been applied at 33 junctions in the Netherlands to evaluate the safety impact of redesigning them (Hydén, 1983). This was before the Dutch developed their technique "Doctor" (Kraay and Van der Horst, 1986).

The Swedish traffic conflicts technique was also applied in a Drive 1 project to evaluate the effectiveness of introducing signal control, based on vulnerable road-user microwave detectors in the Netherlands, Sweden, and the UK (Ekman and Draskóczy (eds.) 1992).
The Swedish traffic conflicts technique was applied in a Drive II project to evaluate the effectiveness of introducing signal control including vulnerable road-user microwave detectors in the UK, Portugal and Greece (Carsten 1995).

In Portugal, the Swedish TCT was applied to evaluate an incident warning system on a rural road (Svensson and Várhelyi 1995). It was also used in a “before and after study” in Portugal aimed to evaluate the effectiveness of implementing low cost measures at T-junctions (Picado-Santos and Rodrigues, 1998).

In Canada, the Swedish TCT was used for diagnostic purposes at eight approaches of signalised junctions and compared to other international techniques, namely the American, French, German, and Canadian technique (Lord, 1994). Lord compared the relationship between conflicts and accidents, but only by considering the original Swedish TCT. The result was in favour of the original Swedish TCT. The modified Swedish TCT was not included in the analysis because no conflicts were recorded according to this definition (Lord, 1994).

The Swedish TCT has also been applied in some developing countries. Almqvist and Hydén (1994) carried out conflict studies at three junctions in Cochabamba, Bolivia. A similar study was completed in Kingston, Jamaica (Almqvist and Hydén, 1994). The technique was used as a diagnostic tool, and it was not modified to suit the local conditions.

None of the studies above, with one exception, an attempt was to modify the Swedish TCT according to the local conditions in the country under study. In fact, all these studies, apart from the Netherlands, were based on a small number of sites, which makes it impossible to perform any validity study. In addition, most of these studies were made for evaluation purposes and the product validity issue was not of concern. Only the Canadian study touched upon the product validity issue but it was based on the original definition of serious conflicts in the Swedish TCT, and the sample size was small.

Therefore, there is a possibility of applying the Swedish TCT other than in Sweden but it should be validated under other conditions than Swedish. Traffic safety conditions are different according to the existing traffic environments. In some countries, pedestrian accidents are more frequent than in others. Common behaviour, which may influence the road-user safety in one traffic environment, is different from what is common in another traffic environment. For instance, the use of passive safety measures like seat belt differs from one country to another and it is known that there is an established relationship between the use of seat belts and the traffic fatalities (Evans, 1991). The outcome of an accident where the use of a seat belt is low would be more severe than if the accident would have occurred in a country with a high use of the seat belt. Accordingly, conversion factors developed in each country might be different assuming that the conflict frequency is the same. On the other hand, conflicts could be more frequent in one traffic environment compared to another, which would also influence the conversion factor values.
To validate the use of Swedish TCT in other traffic environments as an accident predictive tool, one needs to consider the following:

- Investigating the possibility of the application from a practical point of view.
- Investigating if there is a need for any modification to meet the local conditions.
- Considering the resources available, which are always scarce particularly in developing countries.

**Conclusions**

- The present definition of conflict severity considers the speed and the TA-value of the relevant road user.

- The relevant road user is defined as “that road user who took evasive action and his combined conflicting speed and time remaining to accident produced the least severe conflict”.

- The present definition of conflict severity appears to produce less severe conflicts than they might be if the relevant road user is the pedestrian.

- There is a need to reconsider the definition of conflict severity particularly concerning the relevant road-user concept and the threshold that differentiates serious conflicts from non-serious ones.

- It is expected that the inclusion of information that could describe a conflict situation as a dynamic process would provide a deeper insight in conflict mechanism and its relation to accidents.

- In order to consider the use of the Swedish TCT as a predictive tool in any other country than Sweden, there is a need to develop accident to conflict conversion factors that are validated by considering local conditions.
4 Hypotheses for developing the Swedish traffic conflicts technique

The main objective of this work is to improve the Swedish traffic conflicts technique TCT in relation to vehicle-pedestrian conflicts and to eliminate the problems identified with the present Swedish TCT in this regard. The application of the technique in Jordan is a prime objective of this dissertation. A further goal is to study the influence of two different traffic environments on road-user perception of conflict.

To achieve these, a number of hypotheses were formulated as follows:

**Hypothesis 1:** The Swedish traffic conflicts technique can be improved in relation to pedestrian conflicts.

The present definition of vehicle-pedestrian conflicts according to the Swedish TCT seems to produce less serious conflicts than they might be if the relevant road-user is the pedestrian. There is a possibility of improving this definition by considering either an alternative definition of relevant road-user, or/and an alternative approach to define the severity or proximity of conflicts to accidents. The following two sub-hypotheses were formulated:

**Sub-Hypothesis (1-A):** The present vehicle-pedestrian conflict definition could be improved by considering an alternative definition relevant road-user.

The present Swedish TCT defines the RRU as the road user whose speed at time of taking evasive action combined with the time remaining to accident produces the least severe conflict. The severity of the conflict in the present Swedish TCT is linked to performing an evasive action. In an attempt to explore different definitions of relevant road-user, two alternative definitions are introduced for investigation.

**High definition of RRU:** the road-user whose speed at time of the first participant taking evasive action and the time remaining to accident produces the more severe conflict regardless of the performer of the evasive action.

**Low definition of RRU:** the road-user whose speed at time of the first participant taking evasive action and the time remaining to accident produces the least severe conflict regardless of the performer of the evasive action.

**Sub-Hypothesis (1-B):** the present vehicle-pedestrian conflict definition could be improved by considering an alternative definition of conflict severity.

Three approaches were considered to verify sub-hypothesis 1-B.
1) **Threshold approach**

Currently the threshold that differentiates serious conflicts from the rest of conflicts is located above the present threshold, which is intersecting the X-axis of TA-speed graph at 0.5 seconds (Figure 3.5). Four alternative locations of the threshold have been considered in addition to the present threshold (GRX: all conflicts located in severity zone X or higher severity).

1. The threshold that is intersecting the X-axis of the TA-speed graph at 2.25 seconds (Threshold All)
2. The threshold that is intersecting the X-axis of the TA-speed graph at 1.0 second (Threshold GR3)
3. The threshold that is intersecting the X-axis of the TA-speed graph at 0.75 seconds (Threshold GR4)
4. The threshold that is intersecting the X-axis of the TA-speed graph at 0.25 seconds (Threshold GR6).

2) **Severity index approach**

A possible way to understand the conflict event is by viewing the conflict as a dynamic situation.

The inclusion of other dimensions that depict the dynamic characteristics of conflicts within the definition of vehicle-pedestrian conflicts in the Swedish TCT is expected to improve the technique.

Conflict situations consist of three distinct phases, pre-conflict, conflict, and post-conflict. Each phase is described by a number of characteristics as presented in Table 4.1.

<table>
<thead>
<tr>
<th>Table 4.1 Conflict characteristics that describe the conflict as a dynamic process.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Pre-conflict</td>
</tr>
<tr>
<td>Conflict</td>
</tr>
<tr>
<td>Post-conflict</td>
</tr>
</tbody>
</table>
Following the work of Malaterre and Muhlrad (1977), who correlated conflicts to accident, but instead of correlating conflicts to accidents, a set of accident to conflict conversion factors are to be developed based on re-scaling the conflicts by their characteristics. Initial attempts were made to estimate the coefficients that are needed to re-scale the conflicts objectively. However, the collected information did not provide the possibility of performing discriminate analysis, since information on a limited number of sites was available. Thus, the alternative was to make intuitive assumptions that were based on available experience in relation to the investigated conflict characteristics and traffic safety. The basic assumptions that were used for the re-scaling of conflicts were made to reflect how these characteristics are expected to influence the probability of accidents. How these characteristics are supposed to influence the accident to conflict conversion factors (πs)? Not all conflict characteristics presented in Table 4.1 were used for conflict re-scaling in order to calculate the tested severity indices. Table 4.2 summarises the assumptions for estimating the conflict severity indices.

Table 4.2 Assumptions that were used for re-scaling the conflicts to produce conflict severity indices.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Conflict characteristics</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Conflict</td>
<td>Type of vehicle</td>
<td>Conflicts involving passenger car drivers are less likely to produce accidents compared to other vehicles.</td>
</tr>
<tr>
<td></td>
<td>Type of manoeuvre</td>
<td>If the conflict involved non-turning vehicles the probability of producing an accident is higher than if they are involving turning vehicles.</td>
</tr>
<tr>
<td></td>
<td>The possible available time for the road-users to see each other: complexity measure</td>
<td>As the time available for the road-user decreases, the probability of an accident increases, had no road-user taken evasive action.</td>
</tr>
<tr>
<td></td>
<td>Instant measure of exposure: complexity measure</td>
<td>As the situation that preceded the conflict becomes more complex, the probability of an accident increases, had no road-user taken evasive action.</td>
</tr>
<tr>
<td>Conflict</td>
<td>Distance to potential collision point and the conflicting speed combined together to estimate the TA-value and then the severity zone</td>
<td>As conflict severity increases, the probability of a conflict lead to an accident increases, had no road-user taken evasive action.</td>
</tr>
<tr>
<td>Post-conflict</td>
<td>The time separating the road-users immediately after the completion of the evasive action</td>
<td>As time separates the road-users immediately after completion of the evasive action decreases, the probability of producing an accident increases, had no road-user taken evasive action.</td>
</tr>
</tbody>
</table>

The assumption that is assigned to vehicle type was made to reflect the outcome of conflict if nobody has taken evasive action to avoid an accident occurrence. It is expected that the outcome of being involved in accidents with a lorry or van is much higher than a
passenger car. Evans (1991) indicated that the lighter the vehicle is, the less risk it poses to other road-users.

The assumption made in Table 4.2 in connection to the manoeuvre type is based on the fact that conflicts with non-turning vehicles could involve high speed driving. It is known that the speed is positively related to accidents, the higher the speed is the higher the probability of accidents and their severity (Salusjarvi, 1981; Elvik et al., 1989 cited in Vathelyi 1996; Pasanen 1992; Navin and Chow, 1999).

Expectancy is an important factor in defining the reaction time, which is also difficult to assess (Evans, 1991). If the road-users were able to see each other in ample time before the conflict they would expect their counterpart to act and decide their action accordingly. The perception and reaction times are believed to be smaller if the available time for the conflict participants to see each other is shorter. Thus, the probability that conflict will produce an accident is higher, had no road-user taken evasive action to avoid it.

The instant measures of exposure could be used to assess complex situations. As situations become more complex, which could be assessed by an instant measure of exposure, the involved road-users are expected to consider many decisions while passing a junction. They are expected to interact with a number of other road-users. If conflict happens it would impose extra burden on pre-occupied road-users whose ability to take the correct evasive action to avoid an accident is small. The probability of accidents is increased had no road-user taken evasive action.

The following three instant measures of exposure indices were used in the analysis to reflect the complexity of the situation that the involved road-users were subjected to X seconds before being involved in conflicts (X varies from 1 to 4 seconds).

- The number of traffic streams where there are road-users that might directly interact or might influence the involved road-user’s behaviour at X seconds before the conflict.
- The sum of all road-users that happened to be at the scene and might directly interact or might influence the involved road-user’s behaviour at X seconds before the conflict.
- The weighted exposure index that the road-user might be subjected to at the junction X seconds before the conflict.

The sequence listed above was an attempt to handle this complexity issue in three stages. It started by first considering the traffic directions "streams", then how many road-users are in those streams and finally those road-users in different traffic streams were given different weights. The weights were given to reflect the probability of the recorded conflict producing an accident had no road-user taken evasive action. A number of factors were considered while selecting the given weighing, such as road-user type, junction type and manoeuvre type. The assumptions that were utilised in estimating the coefficients were based on the findings reported in Malmö’s calibration study (Grayson, 1984). The results indicated that “vehicle-vehicle” conflicts are much less severe than “vehicle-bicycle” and “vehicle-pedestrian” conflicts (Hydén, 1987). Furthermore, the results showed that
right-angle conflicts and left-turners versus oncoming vehicles were found to be more severe than rear-end, weaving and merging conflicts (Hydén, 1987).

The process validity presented by Hydén (1987) indicated that the accident to conflict ratio increased with the increase of conflict severity. The severity of accidents in each severity zone on the TA-speed graph were estimated based on estimated monetary values of the accident. Hydén illustrated that as the severity zone on the TA-speed graph increases the severity of accidents increase.

It is expected that the close proximity of involved road-users after the completion of evasive action shows how the situation might have ended, had no road-user taken evasive action. The concept of proximity between road-users at the end of evasive action composed one scale that was used to classify conflict severity in Canada and the UK (Brown, 1984, Baguley, 1984). In both techniques, the severity increases as the proximity decreases.

The severity index was calculated for each conflict by multiplying the coefficients that were assumed to translate the listed assumptions into figures. A prerequisite for the coefficient selections was that the sum of the calculated indices should not differ a great deal from the actual number of conflicts, which otherwise would influence the variance of $\pi$.

3) **Conflict sub-group approach**

Conflicts can be classified into different sub-groups that have one common criterion. For example, sub-group that includes conflicts involving a relevant road-user using a speed of at least 30 km/h is believed to be accident related more than other conflicts. Conflict sub-groups can be subdivided in many ways. The most interesting ones are the sub-groups with a safety content. Conflict sub-groups that were used to verify the tested hypothesis were based on the speed, or TA-value, or a measure of exposure.

The verification of hypothesis 1 was based on developing conversion factors that relate accidents to conflicts. Conversion factors were developed for both non-signalised and signalised junctions. It is expected that the conversion factors are different according to the type of junction. To verify hypothesis 1 further the following sub-hypothesis was formulated:

**Sub-Hypothesis (1-C):** Vehicle-pedestrian accident to conflict conversion factors for signalised junctions are different from those for non-signalised junctions.

**Hypothesis 2:** The improved Swedish traffic conflicts technique can also be applied in Jordan.

The Swedish TCT has been used in a number of industrialised and developing countries but without being modified in any way according to the existing local conditions. The
traffic safety conditions in the two countries that were considered in this study, Sweden and Jordan are different in many aspects. The accident problem is more serious in Jordan, which could be attributed to a number of different factors. The transport infrastructure is different in the two countries. The road-network in Jordan is not as large as Sweden. It is of a relatively good standard, but it was not designed to meet the pedestrians needs. Pedestrian facilities are minimal compared to Sweden, and if they are provided they are not always maintained. The vehicle fleet age in Jordan is rather old, which might have adverse effects on safety. The public transport system is poor and it contributes to the accident toll in Jordan. Traffic legislation, enforcement, and road-user awareness are other dimensions that need to be addressed when examining the differences between the two countries. The road-user behaviour is also different in the two countries. The differences in the above factors do influence the road-user' behaviour in the two countries. Therefore, there is a strong indication of the need to modify the Swedish TCT according to the local conditions in Jordan.

The verification of hypothesis 2 was completed by considering the following two sub-hypotheses:

**Sub-hypothesis (2-A):** Conflict definitions that are valid for accident predictions in Sweden are not valid in Jordan.

**Sub-hypothesis (2-B):** Accident predictions for junctions in Jordan made by using conversion factors developed in Sweden are not as good as the predictions made based on factors developed in Jordan.

**Hypothesis 3:** Conflict characteristics and their perception are different in the two countries.

We know that road-users from different traffic environments behave differently in traffic. It is believed that there is a difference in conflict characteristics between the two countries. Conflict characteristics listed in Table 4.1 are partially reflecting the road-users' general behaviour in traffic in the two countries. They were used to examine the road-user perception of conflicts. Not only the conflict characteristics are different, but also how the road-users in the two countries perceive these characteristics is an important issue to be addressed.

An attempt to verify the third hypothesis from three perspectives is explored.

1. **Examining the difference between conflict characteristics recorded in Sweden and Jordan.**

General conflict characteristics are examined to explore the differences due to country. For the purpose of verifying the third hypothesis from this perspective a number of sub-hypotheses were considered.
Sub-Hypothesis (3-A): The relevant road-user type defined according to the present definition varies according to the country under study.

Sub-Hypothesis (3-B): The type of evasive action made and its characteristics differ due to country.

Sub-Hypothesis (3-C): The conflicting speed differs according to the country concerned.

Sub-Hypothesis (3-D): The time remaining to accident differs according to the country concerned.

2. Investigating how the road-users involved in conflicts perceived these situations and assessed their severity.

Interviewing the road-users that have been involved in conflicts enables us to understand how the difference in traffic environments would influence the road-users' perception of conflict characteristics. Road-users' experience of hazards and how they describe and assess their severity were examined by performing a number of interviews with the involved road-users in Sweden and Jordan. The verification of hypothesis 3 from this perspective employed the verification of the following sub-hypotheses:

Sub- Hypothesis (3-E): Pedestrians perceive the severity of conflicts they have been involved in differently in each country.

Sub- Hypothesis (3-F): Pedestrians in the two countries describe their involvement in conflicts differently.

3. Exploring how laymen coming from different traffic environments would assess the severity of conflicts that involved other road-users and were recorded in different traffic environments than their own.

Being involved in conflicts is different from observing conflicts. Road-users involved in conflicts have already been subjected to a hazardous situation and they try either not to admit to their involvement, overestimate, or even sometimes underestimate the severity of the situations. This estimation varies widely, but it simply reflects the road user impression and experience at that moment. Being an observer is not the same as being involved in a conflict. Observers are not stressed or anxious as a result of being involved in conflicts. If their assessment was considered it might be possible to investigate the laymen's general attitude towards risky situations such as traffic conflicts.

Therefore, the verification of the third hypothesis from this perspective deals with conflict severity rating made by a layman group of observers from Jordan and Sweden. To complement this part of the study, the experts' rating was also considered. The expert group is considered as the control group as they should not be biased due to their exposure and experience of different traffic environments.
The basic assumption behind the utilisation of human observers in the Swedish TCT, is that time margin assessment is made continuously by all road-users as part of their normal traffic behaviour (Hydén 1987). It is expected that the laymen severity rating reflect their assessment of risky situations and how they could handle them. Their rating is influenced by the existing traffic environment. Therefore, it is believed that the layman's judgement of conflict severity could provide a deeper understanding of the road-users' general perception of conflict characteristics in different traffic environments.

Based on above, the following sub-hypotheses were proposed:

**Sub-Hypothesis (3-G):** Road-users from different traffic environments have different perception of conflict severity.

**Sub-Hypothesis (3-H):** Laymen's judgement of severity differs from the experts' judgement due to the influence of traffic environment on their perception of conflict severity.
5 Experiment design

For the verification of the proposed hypotheses the experiment was designed as a cross-sectional study performed in real traffic. Two identical studies were made one in Sweden and one in Jordan. The main objective was to develop a database that could be utilised in hypothesis testing. A number of junctions were selected in both countries with and without signal-control. The studies were carried out in daylight and in good weather conditions in order to reduce or eliminate any bias caused by these elements.

In addition, for the purpose of further verifying the third proposed hypothesis, a laboratory study was planned and carried out. Three groups of observers were asked to review a number of conflicts recorded on video and rate their severity.

5.1 Study method

Two methods were employed in this study. An observational method was used to collect conflict data and other road-users' behaviour indicators. The second method was the verbal technique. It was used for interviewing some of the pedestrians involved in conflicts and for rating the severity of the selected conflicts by three groups of observers.

Conflict data and behaviour indicators were extracted from video recordings. The recordings lasted for six hours per day and were performed over two days at non-signalised junction and three days at signalised junctions. Traffic volumes and traffic composition data were also obtained from the video recordings.

The main criterion for selecting junctions was to attain as much as possible comparable conditions in terms of traffic exposure and geometrical conditions at these junctions in Sweden and Jordan. It was impossible to obtain two identical sets of junctions. Different conditions and practices were prevalent in both countries that made the choice of similar junctions problematic. Nevertheless, the selection was aimed at getting comparable conditions as possible.

The selected junctions were filmed using a video camera that was mounted on one of the adjacent high buildings at some distance from the junction. The camera's location was carefully chosen to secure the best possible overview of the junction. At the same time the camera was mounted in a covert position in order not to influence the general behaviour of road-users at the junction. Although every caution was made to secure an overview of the junction, in reality the entire area of the junction was not covered. It was not always possible to get the best view for video recording was carried out. Video recordings needed some advance arrangements including acquiring permission to access the location (where the camera is to be mounted) and obtaining electricity.

Understanding the demands exerted by using video recordings, it is legitimate to raise the question:

Why video recording and not on-site observations?
During the last two decades, conflict observations according to the Swedish traffic conflicts technique were always performed using on-site observers. It is primarily due to constraints that the use of video recording was abandoned and it was only used for training purposes. Video recording was used mainly in this study to manage the observers’ reliability issue. The alternative of not using the video recording is to assign a number of observers to detect conflicts on the selected sites in the two countries. A prerequisite of performing conflict studies by utilising on-site observers is to calibrate the observers’ ability in detecting conflicts against each other in a consistent manner. Since this study was completed in two countries, two alternatives were considered if on-site observers were to collect data. The first alternative was to use two groups of observers. One group is assigned to carry out the study in Sweden and the other in Jordan and their reliability against each other ought to be tested. The second alternative is to assign the same group for both studies. These two alternatives were ruled out due to the cost. It would be extremely expensive to move a group of observers between the two countries or even to assign a group of observers in each country for this study.

Another strategy is to use one observer who could move between Sweden and Jordan without incurring financial burden. This was a possibility that was not considered due to the limited time available to perform the field study, particularly in Sweden. The study in Sweden was intended to be completed in a short time. If the time frame is to be met then two junctions had to be observed at the same time. Based on these arguments it was more logical and practical to use video recordings instead.

Another important reason for video recordings was the type and quality of data that was necessary. This data was too detailed to be collected by on-site observations. Furthermore, the Swedish Traffic conflicts technique is undergoing development to become fully automated and the use of video recording is considered a basic requirement for conflict analysis in this new era of the Swedish TCT.

5.2 Population and sample

The study includes signalised and non-signalised junctions of medium traffic volumes in medium size cities both in Sweden and Jordan. Malmö, is a Swedish city with 254,904 inhabitants according to 1998 census (SCB, 2000). Irbid is a Jordanian city with 380,260 inhabitants according to the 1999 national census. A sample of 42 junctions were selected, twenty of them were in Malmö. Ten of the junctions in Malmö were signalised and the other ten were non-signalised (mostly regulated by a yield sign). Eleven junctions out of the twenty- two selected junctions in Jordan were signalised and the remaining eleven junctions were non-signalised (regulated by a stop sign). However, the driver compliance with a stop sign in Jordan is low. This means that junctions in Jordan are to some degree comparable to junctions regulated by a yield sign in Sweden.

At first it was envisaged that a similar set of junctions would be selected in Irbid. This was not possible to achieve at the time of the study particularly for the signalised junctions in Irbid. During 1996-1997 (the time of study) the Municipality of Irbid installed more of traffic light signals on its roads. It was impossible to select ten signalised junctions that had accident records over a five-year period. Two signalised junctions in Irbid were replaced with two junctions in Amman. These two junctions in Amman were selected in
an avenue that has similar traffic and surroundings as in Irbid. A third signalised junction was added to the signalised junctions in Jordan. Eleven non-signalised junctions were selected in Irbid. The reason behind having eleven junctions of each type in Jordan was to expand the size of the database because the time and financial constraints in Jordan were less than in Sweden.

The selected junctions were mainly four-arm-junctions, two lanes in each approach on the major street and one lane in each approach on the intersecting minor road at non-signalised junctions. The intersecting streets have two lanes in each approach at the signalised junctions. The sites were selected to acquire similar sites in Sweden and Jordan in terms of the junctions’ layout, geometry, and comparable traffic flow range. It was decided not to select the junctions on the basis of previous accident history. The idea behind this is not to induce any bias on the selection that may result from the random nature of accidents. Table 5.1 shows the junction numbers, which from now on, will be considered for identifying the junctions, in addition to some features of the selected junctions in Sweden. Junction names are shown in Appendix A, Table A-1. Pictures of two sites, one is non-signalised junction and the other signalised junction are presented in Appendix A, Figure A-1, Figure A-2.
Table 5.1  Characteristics of the selected junctions in Sweden.

<table>
<thead>
<tr>
<th>Junction number</th>
<th>Junction type</th>
<th>No. of arms</th>
<th>Refuge on the 1\textsuperscript{st} street</th>
<th>Refuge on the intersecting</th>
<th>No. of Lanes on the 1\textsuperscript{st} street</th>
<th>No. of Lanes on intersecting street</th>
<th>Surrounding environment function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Schools; parks</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Shopping areas</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
<td>2</td>
<td></td>
<td>Offices</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
<td>1</td>
<td></td>
<td>Residential apartments; offices</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Offices; parks</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>1</td>
<td></td>
<td>Railway station; offices</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Offices; shopping areas</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Bus terminal; offices</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Bus terminal; offices</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Offices; shopping areas</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>1</td>
<td></td>
<td>Offices; shopping areas</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>17</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Parks; offices; shopping 'market'</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Offices; shopping centres</td>
</tr>
</tbody>
</table>

Table 5.2 shows the junction numbers and the general characteristics of the selected junctions in Jordan. Junction names are shown in Appendix A, Table A-1. Pictures of two sites, one is non-signalised junction and the other signalised junction are presented in Appendix A, Figure A-3, Figure A-4.
Table 5.2 Characteristics of the selected junctions in Jordan.

<table>
<thead>
<tr>
<th>Junction number</th>
<th>Junction type</th>
<th>No. of arms</th>
<th>Refuge on the 1st street</th>
<th>Refuge on the intersecting</th>
<th>No. of Lanes on the 1st street</th>
<th>No. of Lanes on intersecting street</th>
<th>Surrounding environment function</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Non-Signaled</td>
<td>4</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Bus terminal; market, residential area</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Shopping areas; offices</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Shopping areas; offices; schools</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Offices; residential apartments; shopping area</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Offices; residential apartments; bus terminal</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>4</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Residential area; schools</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>4</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Residential area; schools</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>1</td>
<td>Residential area; schools</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Offices; residential apartments</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Residential area; schools</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Residential area; few shops</td>
</tr>
<tr>
<td>32</td>
<td>Signalized</td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Bus terminal; offices</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Offices; shopping areas</td>
</tr>
<tr>
<td>34*</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>1</td>
<td>Offices; hotels</td>
</tr>
<tr>
<td>35*</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Offices; refugee camp</td>
</tr>
<tr>
<td>36*</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Offices; few shops</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Bus terminal; offices; few shops</td>
</tr>
<tr>
<td>38</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Offices; vegetable market</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Offices; schools; few shops</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Offices; schools</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Offices; shopping areas</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>2</td>
<td>Offices; schools</td>
</tr>
</tbody>
</table>

* Selected junctions in Amman while the remaining junctions in Jordan were in Irbid.

Some approaches at several non-signalised junctions in Sweden and Jordan are regulated by either one way or no-entry signs. Unlike Sweden, even some of the signalised junctions
in Jordan have similar signs. More details of this are presented in Appendix A, A-2. The speed limit for intersecting streets on the selected junctions in Sweden is 50km/h. The intersecting streets in Jordan that have refuge have a speed limit of 60km/h and those without refuge have a speed limit of 50km/h.

5.3 Definition of factors and variables to be measured

The conflicts recorded were either non-serious (slight) or serious. They were those involving a collision course and where one or both road-users performed an evasive action. The combined TA-value and conflicting speed of the registered conflicts were classified in severity zones as low as 1, and as high as 11 based on the present definition of conflict severity, see Figure 3.5.

5.3.1 Factors used for hypotheses testing

The influence of the following factors on the severity of the recorded situations and consequently their relation to accidents was investigated.

Type of road-user

The road-user types are the motor vehicle driver and the pedestrian that are involved in vehicle-pedestrian conflicts.

Type of manoeuvre

All vehicle-pedestrian conflicts regardless of the type of vehicle manoeuvre were grouped into one category. However, in the verification of the hypothesis 1 in relation to the severity index approach, the manoeuvre type was divided into turning vehicles and for vehicles driving straight through. Different weights were given for each manoeuvre type.

Type of junction

The junctions that were studied are signalised or non-signalised junctions.

Country

The registered conflicts were grouped according to country of origin.

Subject group

The observers, who were asked to rate the severity of conflicts, were classified into three distinct groups

- Swedish laymen
- Jordanian laymen
- Experts
5.3.2 Variables to be used in hypotheses testing

Number of accidents

All police reported injury accidents that occurred during 1993-1997 at the selected sites in Sweden and Jordan were included.

Conflict numbers and severity

The recorded conflicts are all situations involving collision course, where one of the involved road-users performs sudden evasive action. Only conflicts that involved pedestrians and motor vehicle drivers were registered. Conflicts characteristics were collected including the speed and the TA-value for both road users. Other related information was collected, including an instant measure of exposure, measured at 4, 3, 2, and 1 second(s) before the conflicts. This measure of exposure is defined by the number of vehicles and cyclists present at the junctions who might influenced the behaviour of the participant road-users in a conflict at that measured time and were detected by the conflict observer. In addition, all other pedestrians who cross the zebra crossing, at the approaches that were visible in the recording, were counted if they were expected to influence the behaviour of the participants in the conflict. If no marking (zebra crossing) was available, which was often the case in Jordan, counting was performed at the locations where marking ought to be placed. The possible time available for both road-users to see each other before the conflict, as assessed by the observer, was noted. The distance in time that separated both road-users after the completion of evasive action was also registered and expressed in time. Finally, descriptions of evasive action, which was taken in terms of decisiveness and harshness were also recorded.

Traffic volume

Vehicle and pedestrian volumes were recorded at each junction. Data on cyclist volume on both countries was also collected. Cyclist volume was considerable at the selected junctions in Sweden but not in Jordan. The traffic composition for the vehicle volume was also noted.

Road-user perception of conflicts severity

The road-user’s perception of conflict severity is defined by the road-user’s subjective severity rating of the conflicts they were involved in. The interviewed road-users, which were the pedestrians, were asked the following question “How serious do you think the situation was”. They were requested to mark their answers on a scale of 1 –5 with 1 being no risk of accident and 5 an accident.

Layman observers and experts were asked to rate the severity of some selected vehicle-pedestrian conflicts. This was considered as another perspective of investigating road-user perception of conflict severity.
5.4 Data collection

5.4.1 Accident data

The collected accident data as defined previously are all police reported injury accidents that occurred at the junctions under study from 1993 - 1997. It was possible to collect the data for all the selected junctions in Sweden. On the other hand, detailed police reports data for all accidents in Jordan were only available for the last three years prior to data collection date. The police in Jordan keep hard copies of the reported accidents for three years at most. It was however possible to obtain the data from computer files but with limited details. For purpose of this study, the Municipality of Irbid produced maps that showed the number of accidents by accident type for the last seven years. The author accessed these maps to obtain the any data. However, these maps did not indicate if the accidents occurred in day or night-time. Consequently, it was not possible to consider only accidents that happened during daytime for the same period that corresponds to the period of conducting the conflict observations. All injury accidents that were reported at the selected junctions during five years (1993-1997) were collected. The number of pedestrian police reported accidents at each junction are provided in Table 5.3.
Table 5.3  Collected accident data for the selected junctions (1993-1997).

<table>
<thead>
<tr>
<th>Sweden</th>
<th></th>
<th>Jordan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction number</td>
<td>Pedestrian accidents</td>
<td>Junction number</td>
<td>Pedestrian accidents</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>24</td>
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</tr>
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<td>25</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
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<td>29</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
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<td>32</td>
<td>7</td>
</tr>
<tr>
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<td>1</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
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<td>38</td>
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</tr>
<tr>
<td>19</td>
<td>1</td>
<td>39</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>41</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.4.2  Conflict data

Each signalised junction was filmed for a total of 18 hours over three days. For the non-signalised junctions the duration was 12 hours covering two days. The filming lasted for six hours each day. At junctions 32 and 33 in Jordan, an additional 6 hours were filmed at one approach to cover the whole junction. One approach of junction number 1 and one approach of junction number 15 were filmed for an additional 6 hours because they were partially obscured by the video camera angle during the previous recordings.

The selected junctions in Sweden were filmed in May 1996, and May and June 1997. The sites in Jordan were filmed from September - December 1996. The recording periods
were selected to represent peak and off-peak hours. Most of the Junctions in Sweden were filmed between 11:00 and 17:00 hours and in Jordan between 09:00 and 16:00 hours.

Every effort was made to select a camera location that provided the best overview of the whole junction. In reality, however, the camera’s angle in most of the cases did not cover the whole junction. More details on this are presented in Appendix A, Table A-3 that illustrates the areas covered by the video shots.

Conflict data were extracted from the video recordings for the whole duration of filming at the selected junctions in Sweden. This was not the case for some of the selected junctions in Jordan. Conflict frequency was rather high and sampling to represent the whole duration was used. The sampling was made to acquire enough data representing the situation under investigation. The sampling procedure was based on 25 per cent sampling, i.e. recording all events for a five-minute period every 20 minutes. The expansion to cover the whole period was based on the assumption that the 5 minutes registration is considered representative for the next 15 minutes, having no actual conflict registration. Table A-4 in Appendix A shows the junctions where sampling was made and how it was applied.

The conflicts were registered using a special recording sheet, shown in Appendix B-1. It contained more information than the present sheet that is in use in Sweden. The first part, which is at the top of sheet, contains information about the site under investigation with a small sketch showing the north direction, the time of conflict and the time interval of recording. Information about weather and road surface conditions is also included in this part of the sheet. The second part contains information about the type of involved road-users. The third part provides an attempt to describe the complexity of the situation in general, how long the involved road-users were able to see each other, the number of other road-users (if they formed a group), and finally the instant measure of exposure. The instant measure of exposure is meant to describe the complexity of the traffic situation at the scene measured at 4, 3, 2 and 1 second(s) before the conflict. Only road-users whose presence might influence the involved road-users’ behaviour at 4, 3, 2 and 1 second(s) before the conflict were considered. The fourth part contains a description of the involved road-users’ behaviour before being involved in the conflict.

The general characteristics of the conflict itself are included in the fifth part of the sheet. The conflict severity is assessed by combining the speed at the time of taking evasive action and the TA-value. The TA-value is estimated based on speed and distance estimates. The sixth part covers the evasive action issue, including its type; harshness and whether the road-user has the situation under control (controllability). The sheet also contains an indication of proximity of the road-users to each other. The sheet includes information about the contributing factors that might have caused the conflict. The term "error" was included in the observation sheet to single out the road-user behaviour that caused the conflict, but unfortunately it was not properly completed. Therefore, it was omitted from the analysis. Finally, the sheet includes a sketch of the conflict itself with any additional relevant information. The third, fourth and sixth parts of the observation sheet were not part of the conflict observation sheet that is in use for data collection in the present Swedish TCT. They were included to add further dimensions that are expected to describe the conflict as a dynamic situation.
The total number of vehicle-pedestrian conflicts recorded were 2,658, (1,323 were registered in Sweden and 1,335 in Jordan). These figures are not directly comparable as sampling was applied at some of the selected junctions in Jordan as previously explained. Table 5.4 shows the total number of registered conflicts. Additional details about registered conflicts of each type at each junction are provided in Appendix C, Table C-1.

**Table 5.4** All registered conflicts at the selected junctions.

<table>
<thead>
<tr>
<th>Sweden</th>
<th></th>
<th>Jordan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction number</td>
<td>Pedestrian conflicts</td>
<td>Junction number</td>
<td>Pedestrian conflicts</td>
</tr>
<tr>
<td>1</td>
<td>82</td>
<td>21</td>
<td>37</td>
</tr>
<tr>
<td>2</td>
<td>61</td>
<td>22</td>
<td>76</td>
</tr>
<tr>
<td>3</td>
<td>107</td>
<td>23</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>24</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
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</tr>
<tr>
<td>8</td>
<td>97</td>
<td>28</td>
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**5.4.3 Traffic volume data**

The turning manoeuvres of all vehicles and bicycles at the selected junctions were counted for five minutes time in every twenty minutes of video recording, i.e., making up a 25% sample of video recording periods. The pedestrians that were crossing the marked zebra crossing at the approaches that were visible in the recording were counted. If no marking
was available, which is often the case in Jordan, then the counting was performed at the locations where marking ought to be placed. The counting form was designed as shown in Appendix B-2. The first row in each time interval of counting was filled in with information about motor vehicle data and the second row was for bicycle data. The collected pedestrian counts' information were describing the pedestrian crossing by stating the approach from which the pedestrian starts his crossing and his direction (Appendix B-2).

To expand the traffic volume data from six hours each day to cover the whole day, one procedure was followed in each country. In Sweden, conversion factors (developed earlier by the street division in Malmö’s Municipality) were used to convert the counted traffic volume from six hours into the average daily traffic. As a cross-check recent data, collected by mechanical counters, at some of the approaches at the selected junctions were gathered and conversion factors that correspond to the counted period were calculated and compared with those developed by the street division. Similar results were obtained. Since no conversion factors were available in Jordan, mechanical counting that lasted for 24 hours at some of the selected approaches was carried out and the conversion factors that correspond to the counted periods were acquired. To expand the pedestrian volume data the motor vehicle volume conversion factors were also used for pedestrians and cyclists. The daily traffic volume at the selected junctions was grouped into different types of road-users and presented in Table 5.5.
Table 5.5  Daily traffic volume at the selected junctions.

<table>
<thead>
<tr>
<th></th>
<th>Vehicle volume (vehicles/day)</th>
<th>Bicycle volume (Cyclists/day)</th>
<th>Pedestrian volume (pedestrians/day)</th>
<th>Vehicle volume (vehicles/day)</th>
<th>Bicycle volume (Cyclists/day)</th>
<th>Pedestrian volume (pedestrians/day)</th>
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</table>

|                | 41                           | 36                           | 0.4                               | 25.5                         | 42                           | 30                               | 0.1                               | 0.8                          |

More detail concerning the daily traffic volumes divided into the various turning manoeuvres for vehicles and cyclists and crossing directions for pedestrians is presented in Appendix C, Table C-2, Table C-3 and Table C-4.

The motor vehicle traffic composition was also analysed. Vehicles in traffic streams (traffic directions) were classified into five categories, namely passenger car in private use, taxi, pickup or van, lorry and bus. Table 5.6 shows the traffic composition at the selected junctions, each cell in the table represents the proportion of each category out of the total
traffic in the stream. Table 5.6 suggests that there is a large difference in the composition in the two countries. For example on average, taxis account for one third of traffic in Jordan while they account for around 6 per cent of the traffic in Sweden.

Table 5.6  Traffic composition expressed as percentages at the selected junctions.

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<tr>
<th>Junction Number</th>
<th>Passengers Car (%)</th>
<th>Taxi (%)</th>
<th>Pickup/ Van (%)</th>
<th>Lorry (%)</th>
<th>Bus (%)</th>
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<th>Lorry (%)</th>
<th>Bus (%)</th>
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5.4.4  Road-user interview data

The main objective of the interviews was to assess the road-users' perception of conflict severity by interviewing both pedestrians and drivers that had been involved in conflicts. However, due to financial constraints it was not possible to interview drivers.
Two approaches at two junctions (one in Sweden and one in Jordan) out of the forty-two junctions were selected for this purpose. The main selection criterion was the possibility of recording a considerable number of pedestrian conflicts in a relatively short time. The selection of junctions was not based on the number of accidents that were reported at these junctions.

Site 12, a non-signalled junction that has an average of 20,000 vehicles and 20,600 pedestrians each day was selected to represent the Swedish conditions. Site 32 (a signalised junction with no pedestrian phase, has an average of 26,000 vehicles and 25,500 pedestrians per day) was selected to represent the Jordanian conditions. The number of recorded conflicts at junction number 32 outnumbered the recorded ones at junction 12. The recorded conflicts at junction number 32 were more serious than those recorded at junction number 32. The number of accidents at junction 32 is 7 while it is only 1 accident at junction number 12.

The interviews in Sweden were conducted by a trained conflict observer. A group of three people performed the same task in Jordan. This team in Jordan included a leading observer who conducted interviews and detected conflicts. A further two assistants who carried out interviews only. More than one interviewer on site was required in Jordan because there were too many conflicts happening in a short time. The weather was hot, and the shorter the time spent on site the better the interviewer performance is. One additional aspect was that the sample should contain information about both genders. Due to the social culture in Jordan it is not accepted in certain circumstances, that a male should stop a female and ask her questions and vice versa although to a lesser extent. In fact, street interviews are not common in Jordan. To avoid these social barriers, the team consisted of one female and two males.

Although only pedestrians were interviewed, the interview sheet (Appendix B, B-3) was designed to be applicable if drivers were to be interviewed. The first part of the interview deals with the interviewed road-user’s personal characteristics for example gender and age. The first question dealt with the pedestrian recognition of being involved in an unusual event or “conflict” while crossing the street. The interview was halted if the pedestrian did not recognise being involved in a conflict. The idea behind this is if the conflict left an impression on the involved road-user, he or she would respond immediately because such an event is unusual and it will attract his or her attention. If such an event was regarded as normal or usual, no impression would be left to make the pedestrian recognise the encounter as a conflict. Reminding the pedestrian about what happened was not considered as it will introduce bias to the data.

The following questions dealt with pedestrians’ perception of conflict characteristics that they were involved in, and how they would describe the situation they experienced. They were asked to describe their crossing by assessing their speed and their actions to avoid the consequence of being involved in a conflict. They were asked to assess the speed of the other road-user and report what type of evasive action they took to avoid the e situation. They were also asked to describe how frightened they were as a result of their involvement in such a situation and whom do they think triggered the conflict.
The interviews in Jordan took place in September and October 1997, and the interviews in Sweden in October and November 1997. In total 188 interviews were conducted, 99 in Sweden and 89 in Jordan. The severity of the conflicts was evaluated from the video recordings that were made in conjunction with the interviews. The results as shown in Table 5.7 indicate that conflict selection was made in such a way that a wide range of severity zones is included in the sample. In fact, this was a main criterion that was adopted when selecting conflicts. The severity as presented in Table 5.7 is the severity determined by using the present definition of the Swedish traffic conflicts technique (Hydén 1987).

Table 5.7 The distribution of conflict that involved the interviewed pedestrians over severity zones.

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<th>3</th>
<th>4</th>
<th>5</th>
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</table>

5.4.5 Expert and laymen judgement data

In this part of the study, which was designed as a laboratory study, a small number of variables (i.e. road-user subjective severity assessment) were under investigation and every precaution was made to eliminate bias in the results. Conditions of observations were, as much as possible, similar during various stages of the study. The observers were aware that their performance would be evaluated. The awareness of being under scrutiny is expected to affect the observer’s behaviour, which in turn may cause bias in the results and subsequent validation.

Fifty-one pedestrian conflicts were selected out of 188 conflicts involving pedestrians that were interviewed, 25 from the Swedish data set and 26 from the Jordanian data set. The conflict selection was intended to represent a wide range of severity from the lowest severity to the highest available severity. Two videotapes were edited containing the same conflicts but in different order. The conflicts were randomised to mix conflicts that happened in Sweden with those in Jordan in a random order. The justification for this was that we aimed at minimising the influence of the location of the conflict on the observer’s ability to rate the conflict severity. It is expected that if conflicts recorded in Sweden were edited in sequences then followed by a sequence of conflicts recorded in Jordan, the observer might judge the severity of the conflicts relative to each other and not according to the actual severity of each individual conflict.

Fifty-three observers participated in this part of the study, and they were split into three groups. The first group comprised of Swedish laymen/women and included ten females and ten males. The second group comprised of Jordanian laymen/women and included six females and seventeen males. The third group comprised of experts who have used the
Swedish traffic conflicts technique in their working experience. This group included ten experts one of them was female.

Each observer saw each tape twice; thus each conflict was assessed in terms of severity four times. The procedure that was adopted in this part of the study consisted of the following:

**Step 1:** The observer was shown the first tape and his or her task was

- To estimate the severity of the situations in terms of the probability of an accident.

- To estimate the severity of the situations in terms of the probability of an injury accident.

The observer was asked to rate severity of the situation in terms of the probability of an accident on a five-point scale that corresponds to:

- **Severity grade 1:** Controlled braking or lane change to avoid an accident, but with ample time for manoeuvre.

- **Severity grade 2:** Braking or lane change to avoid an accident with less time for manoeuvre than for a slight conflict, or requiring complex or more severe action.

- **Severity grade 3:** Rapid deceleration, lane change or stopping to avoid an accident resulting in a near miss situation (no time for steady controlled manoeuvre).

- **Severity grade 4:** Emergency braking or violent swerve to avoid an accident resulting in a very near miss situation or minor accident.

- **Severity grade 5:** Emergency action followed by an accident.

This scale is the same scale that was developed by Spicer (1971), where severity grade one and two were considered slight, severity grade 3 to 4 are serious grades and 5 is an accident.

The observer was also asked to rate the severity of the situation as defined by the probability of an injury accident on a five-point scale with one point representing no risk for an injury accident and five an injury accident. The observers rated this similar to their first rating when they were asked to rate the probability of an accident. Their ratings were not included in further analysis because they did not provide a further dimension to their perception of conflict severity.
The observer was given a form that contained a verbal description of the selected conflicts and schematic drawing showing the type of conflicts as shown in Appendix B-4. The observer was asked to mark the severity of each conflict. The observer was allowed to replay the situation as many times as he or she needed.

**Step 2:** The task within the second step is exactly the same as first step but the tape that was shown is tape number two, which contains the same conflicts but in a different order. The form that was used in this step is shown in Appendix B-5.

**Step 3:** In the third step the observer was supposed to carry out more advanced assessment of the conflict characteristics. The observer was again shown tape number one and his or her task comprised of:

- Deciding which one of the involved road-users performed an evasive action to avoid being involved in a accident.
- Estimating the speed for both road-users at the time of taking the evasive action.
- Estimating the distance to the potential accident point for both road-users at the time of taking the evasive action.
- Estimating the severity of the situation in terms of the probability of an accident on the five-point scale explained above.

The observers were given the definitions of the speed and distance to the collision point for the road-user that has made the evasive action. If the other road-user did not take action then his or her speed distance to the potential collision point were estimated at the moment when the evasive action was performed. The observer was given a form to complete and it contains information about the conflict to be assessed. The observer’s task was to mark his assessment on the scales that were specified for this purpose as shown in Appendix B-6.

**Step 4:** In the fourth and final step the observer was required to repeat the same procedure of step three, but with tape number two. The observation sheet is shown in appendix B-7.

Two of the experts have not completed the last step and one of the Jordanian laymen has only completed step one and two.

Each observer watched the tape separately except on two occasions when two observers performed the rating simultaneously but each one of them was carrying out a different task. The first observer was completing the first step and the second observer was completing step number three. The sound was turned off during the observations in order not to influence the observers’ assessment of conflict severity.
Conflicts were objectively assessed using the semi-automatic processing software developed in the department of Technology and Society at the Lund University. The software demands at least four reference points to be measured on the selected sites. Their position is defined on the screen and the movement of the road-user under investigation is then traced throughout the screen. This procedure is preceded by time coding of the event of interest (Odelid and Svensson, 1993; Andersson and Odelid, 1997). The objective data on conflict severity was utilised to compare the subjective ratings of observers.
6 Structure of the analysis

The data analysis used for verifying the proposed hypotheses was completed using the following statistical softwares: SPSS, Statistica, Glim, and Excel. In this chapter, an overview of data processing steps and structure analysis are outlined. The results are presented in the following chapters.

6.1 Data processing

6.1.1 Conflict data processing

The Conflict data was processed into sets that were used to verify the first and the second hypotheses. Three different methodologies were designed to formulate a database. This database was used to test various definitions under each proposed approach of defining conflicts.

Threshold approach

The severity zone of each conflict for each road-user was determined as a function of the estimated TA-value and its relation to the minimum TA-value using the following formula.

\[
\text{Severity zone} = \text{Trunc} \left[ 4 \times \left( 1.5 - (TA - TA_{\text{min}}) \right) \right] + 1
\]  \hspace{1cm} (6.1)

Where,

- **Trunc**: The integer of the estimated value by removing the fractional part of the number.
- **TA**: The estimated TA based on the estimated road-user speed and distance to the potential collision point at the moment of performing any evasive action (sec).
- **TA_{\text{min}}**: The minimum TA-value estimated for the conflicting speed for the threshold that intersects the x-axis of the TA-speed curve at 0 second (sec). It is calculated according to the following formula:

\[
TA_{\text{min}} = \frac{1.5 \times V}{16.7 \times e^{0.0143 \times V}}
\]  \hspace{1cm} (6.2)

Where

- **V**: Conflicting speed (km/h)
- **e**: Euler constant (2.71828)

The selection of the constant 1.5 in formula 6.1 is due to the fact that almost all the recorded conflicts were located under the threshold that is intersecting at 1.5 seconds.
Only a few of them where around the threshold that is intersecting at 2.25 seconds. It is expected that a large number of situations classified in severity zones within the lines that are intersecting the x-axis of the TA-speed graph at 1.5 and 2.25 seconds are likely to occur. These events involved road-users at a distance from the potential collision point, who could not be always covered by the video camera angle that was used for recording conflicts. Therefore the observer was only able to detect a few of the conflicts in such severity zones and they were grouped under conflicts zone (0).

The conflict severity was later classified using the present definition of the relevant road-user (RRU) and the other two proposed alternative definitions (high and low). Conflict severity zone, from now on called (grade), is a fundamental concept that was not only used while investigating the threshold approach as a means for improving the Swedish TCT. It was intensively used while investigating the other two approaches (severity index and conflict sub-group).

**Severity index approach**

There was a need to classify the conflict characteristics that were used to rescale conflicts into categories before estimating the severity indices. This was needed especially for conflict characteristics that were entered as real values such as the instant exposure measurements. It would have been extremely tedious to calculate the severity indices if the values remain real. Severity indices were calculated based on the conflict characteristics that are presented in Table 6.1. The coefficients' symbols that were used in re-scaling the conflicts to calculate the severity indices are presented also in table 6.1. The values that correspond to each coefficient are presented in Appendix D, Table D-1. As illustrated in chapter 4, the intention was to estimate these coefficients objectively. The numbers of selected junctions were not large enough to produce sufficient accident data that could generate various groups of sufficient size to reach statistical significance relationships.
Table 6.1  Conflict characteristics that were used in calculating the severity indices.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Coefficient</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity grade</td>
<td>$\alpha$</td>
<td>Conflict severity grade is obtained by plotting the TA-value and the conflicting speed on TA-speed graph. Conflicts were classified in severity grades that started at 1 grade (conflicts are above the threshold that intersects the x-axis of TA-speed graph at 1.5 seconds). Conflicts that were located out of this threshold were given the grade (0).</td>
</tr>
<tr>
<td>Category</td>
<td>$\beta$</td>
<td>Conflict types were grouped in two distinct categories (Conflicts involving turning vehicles and conflicts not involving turning vehicles).</td>
</tr>
<tr>
<td>TSR</td>
<td>$\delta$</td>
<td>Time separating the involved road-users after the completion of the evasive action: unit in second.</td>
</tr>
<tr>
<td>ATFR</td>
<td>$\gamma$</td>
<td>The possible available time for the involved road-users to see each other before being involved in conflicts: unit is in seconds.</td>
</tr>
<tr>
<td>Vehicle type</td>
<td>$\psi$</td>
<td>The type of vehicle involved in the conflicts. Six types were defined, namely private car driver, cyclists, taxi drivers, van/ pickup driver, and lorry/bus vehicles.</td>
</tr>
<tr>
<td>TSN(4-1)</td>
<td>$\phi_{4-1}$</td>
<td>The sum of the numbers of traffic streams where there were road-users at the scene that might directly interact, or might influence the road-user's (involved of conflict) behaviour, measured at 4, 3, 2, 1 second(s) before the conflict: unit is in numbers.</td>
</tr>
<tr>
<td>DTSN (X1) X varies from 4 to 2</td>
<td>$\phi_{41-421}$</td>
<td>The difference in the sum of the numbers of traffic streams where there were road-users at the scene that might directly interact, or might influence the road-user's (involved of conflict) behaviour, measured at 4, 3, and 2 second(s) and at 1 second before the conflict: unit is in numbers.</td>
</tr>
<tr>
<td>TSS (4-1)</td>
<td>$\lambda_{4-1}$</td>
<td>The sum of all road-users that were at the scene that might directly interact, or might influence the road-user's (involved of conflict) behaviour measured at 4, 3, 2, and 1 second(s) before the conflict: unit is in road-users.</td>
</tr>
<tr>
<td>DTSS (X1) X varies from 4 to 2</td>
<td>$\eta_{41-\eta21}$</td>
<td>The difference in the sum of all road-users that were at the scene that might directly interact, or might influence the road-user's (involved of conflict) behaviour measured at 4, 3, 2 second(s) and at 1 second before the conflict: unit is in numbers.</td>
</tr>
<tr>
<td>WTS(4-1)</td>
<td>$\omega_{4-01}$</td>
<td>The weighted exposure the road-user (involved in conflict) might be exposed to while interacting with other road-users at the junction calculated at 4, 3, 2, 1 second(s) before the conflict: unit is in road-users.</td>
</tr>
<tr>
<td>DWTS (X1) X varies from 4 to 2</td>
<td>$\rho_{41-\rho_{21}1}$</td>
<td>The difference in the weighted exposure calculated at 4, 3, 2 second(s) and the weighted exposure calculated and at 1 second before the conflict: unit is in numbers.</td>
</tr>
</tbody>
</table>

* The definition of number of traffic streams are defined in Figure 6.1, each give a notation of $V_i$. 

75
Figure 6.1 Illustration of traffic streams that were counted and used in the estimation of traffic indices.

The assumptions that are presented in Table 4.2 were translated into coefficients that were used in calculating conflict severity index. The translation of these assumptions has the following implication on the calculated conflict severity index that was estimated for each conflict and repeated for each definition of relevant road-user (RRU):

- As conflict severity zone (grade) increases the conflict severity index increases.
- As time separating the road-users after the evasive action (TSR) decreases the conflict severity index increases.
- As the time available for the road-user to see each other before the conflict (ATFR) decreases the conflict severity index increases.
- Conflict severity index is smaller if the conflict involved a passenger car when compared to a conflict involving some other type of vehicle.
- As the instant exposure index increases, the conflict severity index increases.

Two out of the three instant exposure indices that are presented in Table 6.1, to reflect the complexity of the situation measured 4, 3, 2, and 1 second(s) before conflicts, were straightforward in their calculations [TSN (1...4) and TSS (1...4)]. They were easily calculated by adding the number of traffic streams where there were road-users or adding
### Table 6.2 Definition of the investigated severity indices.

<table>
<thead>
<tr>
<th>Conflict severity index</th>
<th>Conflict characteristics</th>
<th>Phase of conflict</th>
</tr>
</thead>
</table>
| S                       | 1) Severity grade  
2) Category                                         | Conflict          |
| SC                      | 1) Severity grade  
2) Category  
3) Distance to collision after the completion of the evasive action | Conflict  
Pre-conflict |
| SCT                     | 1) Severity grade  
2) Category  
3) Distance to collision after the completion of the evasive action  
4) The available time for the involved road-users to see each other before the conflict | Conflict  
Pre-conflict  
Post-conflict |
| SCTA                    | 1) Severity grade  
2) Category  
3) Distance to collision after the completion of the evasive action  
4) The possible available time for the involved road-users to see each other before the conflict  
5) Vehicle type | Conflict  
Pre-conflict  
Post-conflict |
| SCTAV                   | 1) Severity grade  
2) Category  
3) Distance to collision after the completion of the evasive action  
4) The possible available time for the involved road-users to see each other before the conflict  
5) Vehicle type  
6) Instant measure of exposure | Conflict  
Pre-conflict  
Post-conflict |

*definitions are presented below.

Two approaches were used in calculating the severity indices that include traffic exposure index as one component. First, the severity indices were calculated at each distinct time where the exposure measurement were made, specifically 4 or 3 or 2 or 1 second(s) before the conflicts. For example, N4 is calculated by considering the exposure at 4 seconds before the conflict as one of its components. Alternatively, as a product of the sequence of exposure indices calculated at each measured time. For instance, N4321, is calculated by considering the exposure at 4, 3, 2 and 1 second(s) before the conflict. Second, the severity indices were calculated by considering the change in the instant exposure over the measured time. They were envisaged as a measure to examine the change over time in the complexity of the situation that preceded the conflicts (D41, S41, W41). For example, D41 stands for severity index that includes the difference between the number of traffic streams where there were road-users measured at 4 seconds (TSN4) and at 1 second (TSN1) before the conflict, as one of its components.
Table 6.3 illustrates the formulas that were used in calculating the various severity indices. Detailed definition of each severity index is shown in Appendix D, Table D-3.

### Table 6.3  Formulas that were used in calculating the severity index.

<table>
<thead>
<tr>
<th>Severity indices based on a number of conflict characteristics without including any instant exposure index</th>
<th>Severity indices including an instant measure of exposure as one of its components: the summation of relevant traffic stream numbers</th>
<th>Severity indices including an instant measure of exposure as one of its components: the summation of roadusers in the relevant traffic streams</th>
<th>Severity indices including as an instant measure of exposure as one of its components: the weighted traffic exposure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S=α</td>
<td>N4=α x β x δ x γ x ψ x φ4</td>
<td>S4=α x β x δ x γ x ψ x λ4</td>
<td>W4=α x β x δ x γ x ψ x ω4</td>
</tr>
<tr>
<td>SC=α x β</td>
<td>N43=α x β x δ x γ x ψ x φ4 x φ3</td>
<td>S43=α x β x δ x γ x ψ x λ4 x λ3</td>
<td>W43=α x β x δ x γ x ψ x ω4 x ω3</td>
</tr>
<tr>
<td>SCT=α x β x δ</td>
<td>N432=α x β x δ x γ x ψ x φ4 x φ3 x φ2 x φ1</td>
<td>S432=α x β x δ x γ x ψ x λ4 x λ3 x λ2</td>
<td>W432=α x β x δ x γ x ψ x ω4 x ω3 x ω2</td>
</tr>
<tr>
<td>SCTA=α x β x δ x γ</td>
<td>N4321=α x β x δ x γ x ψ x φ4 x φ3 x φ2 x φ1 x</td>
<td>S4321=α x β x δ x γ x ψ x λ4 x λ3 x λ2 x λ1</td>
<td>W4321=α x β x δ x γ x ψ x ω4 x ω3 x ω2 x ω1</td>
</tr>
<tr>
<td>SCTAV=α x β x δ x γ x ψ</td>
<td>N3=α x β x δ x γ x ψ x φ3</td>
<td>S3=α x β x δ x γ x ψ x λ3</td>
<td>W3=α x β x δ x γ x ψ x ω3</td>
</tr>
<tr>
<td></td>
<td>N32=α x β x δ x γ x ψ x φ3 x φ2 x φ1</td>
<td>S32=α x β x δ x γ x ψ x λ3 x λ2 x λ1</td>
<td>W32=α x β x δ x γ x ψ x ω3 x ω2 x ω1</td>
</tr>
<tr>
<td></td>
<td>N321=α x β x δ x γ x ψ x φ3 x φ2 x φ1 x</td>
<td>S321=α x β x δ x γ x ψ x λ3 x λ2 x λ1 x λ2</td>
<td>W321=α x β x δ x γ x ψ x ω3 x ω2 x ω1 x ω2</td>
</tr>
<tr>
<td></td>
<td>N2=α x β x δ x γ x ψ x φ2 x φ1</td>
<td>S2=α x β x δ x γ x ψ x λ2 x λ1</td>
<td>W2=α x β x δ x γ x ψ x ω2 x ω1</td>
</tr>
<tr>
<td></td>
<td>N21=α x β x δ x γ x ψ x φ2 x φ1 x</td>
<td>S21=α x β x δ x γ x ψ x λ2 x λ1 x λ1</td>
<td>W21=α x β x δ x γ x ψ x ω2 x ω1 x ω1</td>
</tr>
<tr>
<td></td>
<td>N1=α x β x δ x γ x ψ x φ1 x</td>
<td>S1=α x β x δ x γ x ψ x λ1</td>
<td>W1=α x β x δ x γ x ψ x ω1</td>
</tr>
<tr>
<td></td>
<td>DN41=α x β x δ x γ x ψ x φ41</td>
<td>DS41=α x β x δ x γ x ψ x η41</td>
<td>DW41=α x β x δ x γ x ψ x ρ41</td>
</tr>
<tr>
<td></td>
<td>DN31=α x β x δ x γ x ψ x φ31</td>
<td>DS31=α x β x δ x γ x ψ x η31</td>
<td>DW31=α x β x δ x γ x ψ x ρ31</td>
</tr>
<tr>
<td></td>
<td>DN21=α x β x δ x γ x ψ x φ21</td>
<td>DS21=α x β x δ x γ x ψ x η21</td>
<td>DW21=α x β x δ x γ x ψ x ρ21</td>
</tr>
</tbody>
</table>

The numbers between parentheses are the index numbers.
Chapter Six

Structure of analysis

the number of all road users in the vicinity of the junction for indices TSN (1…4) and TSS (1…4) respectively. On the other hand, the calculation of the WTS (1…4) index was not directly calculated based on the number of road-users that were present at the junction. Different weights were given to the presence of the other road-users based on the assumptions that they reflect the probability of injury accident if the involved road-user interacts with any of them. The weights were allocated by taking into account the type of road-user and manoeuvre type [Appendix D, Table D-2].

The coefficients that were used in calculating the severity indices were selected so that the summation of the re-scaled conflicts would not differ to a large extent from the actual number of conflicts. This would otherwise influence the variance of accident to conflict conversion factors ($\pi$).

Forty-three conflict severity indices were calculated as a multiplication of the coefficients that describe different phases of conflict as presented in Table 6.2. The aim was to arrive at visualising the conflict as a dynamic situation, which consists of three phases, namely pre-conflict, conflict, and post conflict. The first five indices were calculated without taking any traffic exposure index into consideration, while the remaining thirty-six indices included an instant measure of exposure as one of their components. The calculations were processed in steps, first severity index S is just a re-scaling of the conflicts according to their severity grades. The types of vehicle manoeuvre was then added to calculate severity index SC. More details on severity index calculations are presented in Table 6.2, which shows the investigated conflict severity indices including the conflict characteristics that used for describing each phase of the conflict.
Conflict sub-groups

The coding that was used for developing severity indices formed the basis for conflict sub-groups. The idea is to achieve conflict sub-groups on the basis of one conflict characteristic at a time. The criteria that were used to identify the different sub-groups for analysis are presented in Table 6.4.

Table 6.4  The criteria used to identify conflict sub-groups that are expected to be accident related.

<table>
<thead>
<tr>
<th>Conflict characteristic</th>
<th>Sub-group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Road-user type</td>
<td>Private car</td>
</tr>
<tr>
<td>Number of road users within a group</td>
<td>One</td>
</tr>
<tr>
<td>Available time for the road-users to see each other (ATFR) in second</td>
<td>1 ≤ x</td>
</tr>
</tbody>
</table>

Instant measure of exposure

<table>
<thead>
<tr>
<th>Instant traffic stream number exposure index in number (TSNₐ,TSNₚ)</th>
<th>x ≤ 0</th>
<th>0 &lt; x ≤ 1</th>
<th>1 &lt; x ≤ 2</th>
<th>2 &lt; x ≤ 3</th>
<th>3 &lt; x ≤ 4</th>
<th>4 &lt; x ≤ 5</th>
<th>5 &lt; x ≤ 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instant traffic stream summation exposure index in second (TSSₐ,TSSₚ)</td>
<td>0 ≤ x &lt; 1</td>
<td>1 ≤ x &lt; 2</td>
<td>2 ≤ x &lt; 3</td>
<td>3 ≤ x &lt; 4</td>
<td>4 ≤ x &lt; 5</td>
<td>5 ≤ x &lt; 10</td>
<td>10 ≤ x</td>
</tr>
<tr>
<td>Weighted instant traffic exposure index (WTSₐ,WTSₚ)</td>
<td>x ≤ 0</td>
<td>0 &lt; x ≤ 1</td>
<td>1 &lt; x ≤ 2</td>
<td>2 &lt; x ≤ 3</td>
<td>3 &lt; x ≤ 4</td>
<td>4 &lt; x ≤ 5</td>
<td>5 &lt; x</td>
</tr>
<tr>
<td>Conflicting speed (km/h)</td>
<td>x &lt; 10</td>
<td>10 ≤ x &lt; 20</td>
<td>20 ≤ x &lt; 30</td>
<td>30 ≤ x &lt; 40</td>
<td>40 ≤ x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TA-value (sec)</td>
<td>x &lt; 0.5</td>
<td>0.5 ≤ x &lt; 0.75</td>
<td>0.75 ≤ x &lt; 1</td>
<td>1 ≤ x &lt; 1.25</td>
<td>1.25 ≤ x &lt; 1.5</td>
<td>1.5 ≤ x</td>
<td></td>
</tr>
<tr>
<td>Time separating road users after the completion of evasive action (TSR) in second</td>
<td>x &lt; 0.5</td>
<td>0.5 ≤ x &lt; 0.75</td>
<td>0.75 ≤ x &lt; 1</td>
<td>1 ≤ x &lt; 1.25</td>
<td>1.25 ≤ x &lt; 1.5</td>
<td>1.5 ≤ x</td>
<td>Stop up to 4 sec</td>
</tr>
</tbody>
</table>

The method adopted to process the data and to arrive at the criteria shown in Table 6.4, is as follows:
1. A number of sub-groups were formed for each characteristic of conflicts. The main intention was to have similar numbers of cases in each conflict sub-group that described the same conflict characteristics. However, some difficulties were experienced in achieving this target. A compromise was made to combine two sub-groups together and have a new criterion, which describe one conflict characteristics, for the merged sub-group.

2. The sub-group mentioned in 1 was repeated twice, first sub-group with all conflicts and then with serious conflicts only based on the present definition of conflicts (threshold GR5).

3. All the three definitions of the relevant road-user were scrutinised.

4. As a result, we had conflict sub-groups for the six groups of conflicts indicated by Table 6.5.

<table>
<thead>
<tr>
<th>Conflict group</th>
<th>Relevant road-user definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>All conflicts</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Serious conflicts (defined based on the present threshold GR 5)</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>

**Table 6.5** The six main groups of conflicts.

---

### 6.1.2 Traffic data processing

The collected data were extended to cover 24 hours of traffic volume. Mechanical counting data that covered 24 hours for the junctions in Jordan were collected. This data was utilised to extrapolate the six-hour traffic volume during the field study to represent 24 hours traffic volume. A set of factors that were developed earlier in Malmö were used for the same purpose in Sweden.

For analysis purposes, the traffic volume index “Sum product of pedestrian vehicle traffic streams (Spc)" was used. It was calculated as the sum of the product of all vehicles that were intersecting the pedestrian crossing at each junction approach times the pedestrian volume at that approach. The formula used to calculate this index as follows and is presented in formula 6.3 and the definition of traffic streams are presented in Figure 6.1.

\[
\text{Sum product of pedestrian-vehicle traffic streams (Spc)} = (P_{14} + P_{15}) \times (V_{1} + V_{14} + V_{8} + V_{7}) + (P_{20} + P_{20}) \times (V_{1} + V_{1} + V_{9} + V_{8}) + (P_{15} + P_{19}) \times (V_{5} + V_{6} + V_{2} + V_{3}) + (P_{16} + P_{12}) \times (V_{e} + V_{5} + V_{10} + V_{7})
\]

(6.3)
In addition, the total vehicle entry volume was calculated as the summation of all vehicles that enter the junction. The pedestrian inflow was calculated as the sum of all pedestrians crossing all the junction approaches.

6.1.3 Other data

Interviews, and laymen and expert judgement data required minimal work. The main part of the processing was to define the severity zone according to the three alternative definitions of RRU, namely the present, high, and low. The objective data that were extracted using the semi-automatic objective technique that was developed at LTH. This data was used to determine the objective severity of conflicts. The three alternative relevant road-user definitions were used in classifying the conflict severity.

In addition, simple data coding the answers in the interviews was made to simplify the analysis.

6.2 Methods of analysis

For verifying the proposed hypotheses a number of statistical tools were employed. The verification of the first two hypotheses was completed by developing a set of accident to conflict conversion factors for the various investigated definitions. These conversion factors were used for accident prediction purposes. The Generalised Linear Modelling (see e.g. Kulmala, 1995) was also used as an introductory approach for determining the best conflict sub-group that could be related to accidents. Other tests were also used while verifying the first two hypotheses, including the Mann Whitney test and Kolmogorov-Smirnov test (K-S test). The verification of the last hypothesis was completed by running some descriptive analysis and the analysis of variance test.

A description of the methods employed is explained below.

6.2.1 Conversion factors

The verification of the first two hypotheses was mainly achieved by developing a set of conversion factors that relate the number of conflicts, defined according to each tested approach, to accident numbers. Conversion factors were validated against each other by using the Hauer and Gärdner (1986) validity approach, to determine the most valid definition of a serious conflict based on the variance of conflict to accident conversion factors. However, it was not only the variance of the accident to conflict ratio that was used to determine the validity of the new definition of conflict as a tool for accident prediction. The coefficient of variation of the accident to conflict ratio was also used since it relates the variance of the conversion factor to its value.

In addition, the following two criteria were used to validate a new definition of vehicle-pedestrian conflict:
• The coefficient of variation of accident predictions.
• The probability of observing the actual number of accidents given the predicted numbers.

The variance of conflict to accident conversion factors

According to Hauer and Gärder (1986) the operational definition of a valid traffic conflicts technique is:

"A technique (method, device) for the estimation of safety is “valid” if it produces unbiased estimates of expected number of accidents the variance of which is deemed to be “satisfactory”.

Therefore, the validity is a matter of degree and is measured by the variance of the estimate. Hauer (1982) and before Hydén (1977) have related the rate of conflict occurrence and the expected rate of accident occurrence by the following formula:

\[
\left( \frac{\text{Number of accidents expected}}{\text{to occur on any transport unit during a certain period of time}} \right) = \left( \frac{\text{Number of conflicts occurring on any transport unit in that time}}{\text{Accident-to-conflict ratio for that transport unit}} \right)
\]

Or in symbol notation

\[
\lambda = C \times \pi \quad (6.4)
\]

The estimate \( \hat{\lambda} \) is calculated using an estimate of the number of conflicts \( \hat{\epsilon} \) occurring during that period of time \( c \) and multiplying it by an estimate \( \hat{\pi} \) of the accident to conflict ratio \( \pi \).

The estimate of \( \epsilon \) is obtained from field studies that could last for a number of days. In this research, two days of conflict studies were completed for non-signalised junctions and three days for signalised junctions. The number of conflicts observed \( \epsilon \) is then multiplied by the sampling ratio so that the estimate \( \hat{\epsilon} \) covers the same period during which accident data were collected. The variance of \( \hat{\epsilon} \) is estimated as function of the estimate of \( \epsilon \) and the sampling ratio in mathematical terms:

\[
\text{VAR} (\hat{\epsilon}) = C \times (N/n)^2 \quad (6.5)
\]

Where,

\( C \) = the number of conflicts observed;
\( N \) = the time period during which accident data were collected;
\( n \) = the time period during which conflict data were collected.

An estimate of accident to conflict ratio (conversion factor) is calculated as a sample mean \( \bar{\pi} \). It is an estimate of the expected value of the \( \pi \)'s, \( E[\pi] \). Hauer and Gärder (1986) have
proposed two methods for estimating the variance of \( \{ \pi \} \), namely the method of moment and the method of maximum likelihood. The second method (method of maximum likelihood was adopted method for estimating the variance of \( \{ \pi \} \), seems to perform better than the moment method (Hauer and Garder, 1986). A software program by Kulmala (1998) was used for this purpose. It was not always possible to estimate the value that maximises the likelihood function. When this has happened the author reverted to the moment method. The method of moments was used. However, it produced negative values for the variance for, which is a drawback of the method as pointed out by Hauer and Garder (1986). They recommended assuming the variance to be very small and could be considered as zero whenever such problem was encountered. If all definitions for one type of junctions have negative variances, which are equated to zero, it is impossible to compare them. The sample variance was then used to estimate the variance. This was the only solution to compare different definitions if all of them yield negative variances.

The coefficient of variation is calculated for each definition of serious conflict by using the following formula and expressed in percentage:

\[
CoV(\pi) = \frac{\sqrt{VAR(\pi)}}{\pi}
\]  

(6.6)

The minimum coefficient of variation of the accident prediction

Hauer and Garder (1986) proposed the following formula to estimate the variance of the predicted number of accidents at the junctions that were used for validating the developed model in this study.

\[
VAR(\hat{\lambda}) = c^2 \times VAR(\pi) + \pi^2 \times VAR(\hat{\varepsilon}) + (\pi - E[\pi])^2 \times \left( \text{VAR}(\hat{\varepsilon}) + c^2 \right) + \text{VAR}(\pi) \times \text{VAR}(\hat{\varepsilon})
\]  

(6.7)

The coefficient of variation of this prediction at each junction is determined by using formula 6.6 instead of dividing the square root of the \( \text{VAR}(\hat{\lambda}) \) by its \( \hat{\lambda} \). The average of all coefficients of variation for junctions was calculated and used for validation purposes. The serious conflict definition that produces the minimum average coefficient of variation of the accident predictions is considered as one of the most valid definitions of conflict severity. It is not necessarily the best as illustrated later in this section.

The probability of observing the actual number of accidents

The definition of serious traffic conflict that produces the highest probability of observing the actual number of accidents is considered as one of the most valid definitions. We assume that the accident occurrence follows the Poisson distribution and calculate the probability of observing the actual number of accidents given that the predicted value is obtained by the tested definition.

\[
p(X|\lambda) = \frac{e^{-\lambda} \lambda^X}{X!}
\]  

(6.8)
Where,

\[ P(X_i | \hat{\lambda}_i) : \text{Probability of observing the actual number of accidents at the} \]

junction under scrutiny, given that the predicted value is estimated;

\( X: \) \quad \text{The actual number of accidents;}

\( \hat{\lambda}: \) \quad \text{The predicted number of accidents.}

The aim is to maximise the combined probability of observing the actual number of accidents at all of the sites that were used for validation purposes.

\[ P(X) = P(X_1 | \hat{\lambda}_1) \times P(X_2 | \hat{\lambda}_2) \times \ldots P(X_i | \hat{\lambda}_i) \]  \hspace{1cm} (6.9)

**Ratio to the best**

The most valid definition is the one that produces

a) the minimum coefficient of variation of \( \pi \);

b) the minimum average coefficient of variation of the accident predictions;

c) the highest probability of observing the actual number of accidents.

The criteria (a) and (b) produced similar results in most of the cases, which was not the case with the (c). Therefore, there is a need to consider a methodology that could combine all criteria. The method that was used is the so-called “ratio to the best”. The steps that were used to obtain the ratio to the best were as follows:

The definition of serious conflicts that produced the minimum value of the coefficient of variation of \( \text{CoV}(\pi)_{\text{min}} \) was determined. It was considered as the reference value. Each coefficient of variation of another alternative definition of serious conflict \( \text{CoV}(\pi) \) was divided by that reference value.

The definition of serious conflicts that produced the minimum value of the average coefficient of variation of the prediction \( \text{CoV}(\hat{\lambda})_{\text{min}} \) was also determined. It was considered as the reference value. Each average coefficient of variation of another alternative definition of serious conflict \( \text{CoV}(\hat{\lambda}) \) was divided by that reference value.

The definition of serious conflict that produced the maximum value of the probability function that describes the probability of observing the actual number of accidents given the prediction function \( P(X)_{\text{max}} \) was determined. It was considered as the reference value. The probability value of another alternative definition of serious conflict \( P(X) \) was divided by that reference value.
In order to be able to combine them together all these ratios should have either 1 as the maximum or minimum. Therefore, the inverse of the probability function was used. It was then possible to multiply the three ratios together to obtain the overall ratio to the best. The validity is better, the smaller the ratio to the best.

### 6.2.2 Testing the difference between the estimated conversion factors.

To test if there is any difference between the estimated conversion factors for the signalised junctions and those for non-signalised junctions, the Mann Whitney test was used (Marascuilo & McSweeney 1977). It is a test to compare two population means without assuming normality for the distribution. It is based on the analysis of the ranks of the sample observations.

Two samples are selected, and each consists of a number of observations \((n_1\) and \(n_2\)). The two data sets are combined in one set and all the observations are ranked in ascending order (from the smallest rank to largest rank). The sum of the ranks \((\text{rank sum} \ T)\) is calculated for each sample \((T_1, T_2)\). Mann Whitney test value is calculated for each sample by applying equations (6.10 and 6.11).

\[
U_1 = n_1n_2 + \frac{n_1(n_1 + 1)}{2} - T_1
\]

\[
U_2 = n_1n_2 + \frac{n_2(n_2 + 1)}{2} - T_2
\]

For the two-tailed test the smallest \(U\) is used in testing the hypothesis that the two distributions are identical at a given significant level \((\alpha)\). The hypothesis is rejected if \(U \leq U_\alpha\) where \(P(\text{U} \leq U_\alpha) = \alpha/2\). \(U_\alpha\) is the value such that \(P(\text{U} \leq U_\alpha)\) is equal to half of \(\alpha\); \(P\) is the probability. The selected significant level for the purpose of this study is 5 per cent.

The above method was used to detect any difference in the conversion factors due to the type of junction "Sub-Hypothesis 1-C". The same test was applied to explore if there is any difference between conversion factors developed in Sweden and Jordan.

### 6.2.3 Similarities between conflict distributions

As part of the verification of hypothesis 2, the distributions of conflicts over severity grade in the two countries were compared to pinpoint any difference(s). The method employed was the Kolmogorov–Smirnov or K-S test (Marascuilo & McSweeney 1977). The null hypothesis in this test states that the two samples are from identical populations. The alternative hypothesis states that the distributions are different.

According to this test, the observations in each sample are ranked in order. The cumulative relative frequencies for each sample are determined. Then, the cumulative frequency of each observation from the first sample is subtracted from the corresponding cumulative frequency in the second, and the absolute value of the difference is determined. The maximum difference between the samples is called K-S value. This
estimated value is compared with the critical value obtained at 0.05 significant value for two-sided test. If the K-S is greater than the critical value, the null hypothesis is rejected and the conclusion is that the two distributions are not identical.

6.2.4 Laymen and experts severity rating comparison.

Pearson correlation coefficient was used to evaluate the observer reliability in rating conflicts in a consistent manner. External reliability assesses the agreement between the observer rating and objective measure. It was tested by estimating Pearson correlation coefficient. The objective severity of conflicts that were determined formed the basis for grouping them under various threshold definitions. Conflicts’ subjective severity rated by laymen and experts for each objective conflict severity grade were compared to assess if there are any differences that could be attributed to the traffic environment by performing analysis of variance test (ANOVA).

6.3 The adopted approach for analysis

To verify the first two hypotheses, it was decided to develop the conversion factors and the CoV (π) after studying two groups (non-signalised and signalised) of seven junctions in Sweden and two groups of eight junctions each in Jordan. Further two groups of three junctions in the respective countries were utilised for validation. The validation process consists of estimating the CoV of the prediction (λ̂) and the probability of observing the actual number of accidents given the predicted number.

Over three hundred alternative definitions to the present definition of a serious conflict were put forward. Only the definitions that produced the lowest variances of accident to conflict conversion factors VAR \{π\} were used for the further validation. In addition, the selected definitions should have safety-related contents in relation such as short TA-value and/or a high speed. All alternative definitions included under the threshold approach were considered regardless of their accident to conflict conversion factor variance. There were not many definitions under the threshold approach. In addition, this approach forms the basis for the present definition of a serious conflict in the Swedish TCT.

Accident predictions and the variances of accident to conflict ratio VAR \{λ\} formed the basis for verification of the first two hypotheses.

The validity of various definitions of conflicts was investigated as follows:

- Definitions under each approach were compared to each other and to the present definition of serious conflicts in the Swedish TCT in order to obtain the most valid definition of conflicts.

- The most valid definitions for each approach were compared to each other to determine the most valid definition of conflict for each junction type in the respective countries.
The verification of the second hypothesis was investigated as follows:

Define the most valid definition of conflicts based on data collected in Jordan. The same procedure was adopted to validate conflict definition in Sweden as shown above. The most valid definitions of conflicts in each country were compared.

Predictions based on conversion factors developed for junctions in Jordan were compared to those based on conversion factors developed in Sweden for predicting the accidents in Jordan.

The verification of the third hypothesis in relation to the general characteristics of conflicts was completed by analysing all recorded conflicts from all junctions in each country. None of the validated junctions was excluded. Interview data and layman and expert severity judgements were utilised in this process. The objective data calculated by using the semi-objective technique (developed at LTH) formed the basis for comparing the subjective severity rating of the laymen and experts.
7 Validation of a traffic conflicts technique for different environments

7.1 The improvement of the Swedish TCT

The hypothesis under investigation is "The Swedish traffic conflicts technique can be improved in relation to pedestrian conflicts".

The improvement of the Swedish TCT was investigated by considering two sub-hypotheses:

Sub-Hypothesis (1-A): The present vehicle-pedestrian conflict definition could be improved by considering an alternative definition relevant road-user.

The three relevant road-user (RRU) definitions were examined.

1. The present definition: the road user whose speed at time of taking evasive action combined with the time remaining to the accident produces the least severe conflict.

2. High definition of RRU: the road-user whose speed at time of the first participant taking evasive action and the time remaining to accident produces the more severe conflict regardless of the performer of the evasive action.

3. Low definition of RRU: the road-user whose speed at time of the first participant taking evasive action and the time remaining to accident produces the least severe conflict regardless of the performer of the evasive action.

Sub-Hypothesis (1-B): the present vehicle-pedestrian conflict definition could be improved by considering an alternative definition of conflict severity.

Three approaches were considered, specifically, threshold, severity index, and conflict subgroup approach. A number of alternative definitions of conflicts were considered under each approach. The results of the analysis for each type of junction are presented below.

7.1.1 Non-signalised junctions in Sweden

The threshold approach

The four alternative thresholds that were considered in addition to the present one (GR5), which intersects the X-axis of the TA-speed graph at 0.5 seconds (Figure 7.1) were the following:
• The threshold that is intersecting the X-axis of the TA-speed graph at 2.25 seconds (Threshold All)
• The threshold that is intersecting the X-axis of the TA-speed graph at 1.0 second (Threshold GR3)
• The threshold that is intersecting the X-axis of the TA-speed graph at 0.75 seconds (Threshold GR4)
• The threshold that is intersecting the X-axis of the TA-speed graph at 0.25 seconds (Threshold GR6)

The inclusion of threshold “all” does not mean that no threshold case was considered. The selected conflicts were of enough severity that might be of interest while locating the threshold. As illustrated before, almost all of them were located under the threshold that is intersecting at 1.5 seconds and only a few of them where around the threshold that is intersecting at 2.25 seconds.

![Graph showing the tested alternative definitions of the threshold levels that differentiate serious from non-serious conflicts.](image)

**Figure 7.1** The tested alternative definitions of the threshold levels that differentiate serious from non-serious conflicts

The results of validating the alternative definitions of conflicts under the threshold approach, as accident prediction tools for non-signalised junctions in Sweden (Table 7.1). The conversion factors “π”, which is defined as the accident to conflict ratio, developed for these definitions and their variances are presented in Table 7.1.
Table 7.1 The validity of conflict definitions based on various thresholds and relevant road-user definitions for non-signalised junctions in Sweden.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Relevant road-user definition</th>
<th>Mean $\pi$ 10^5</th>
<th>Variance $\text{VAR} (\pi)$ 10^{-12}</th>
<th>CoV $\mu (\pi)$ %</th>
<th>CoV $\hat{\lambda}$ %</th>
<th>$\frac{\text{CoV} (\pi_i)}{\text{CoV} (\pi_{\text{min}})}$ A</th>
<th>$\frac{\text{CoV} (\hat{\lambda}<em>i)}{\text{CoV} (\hat{\lambda}</em>{\text{min}})}$ B</th>
<th>$\frac{1}{P(X_i)}$ P(X_i)</th>
<th>Overall ratio to the best A × b × c</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td></td>
<td>8.75</td>
<td>63.20</td>
<td>91</td>
<td>99</td>
<td>17.30</td>
<td>1.42</td>
<td>1.13</td>
<td>2.46</td>
</tr>
<tr>
<td>GR3</td>
<td>Present</td>
<td>9.58</td>
<td>65.50</td>
<td>84</td>
<td>93</td>
<td>15.00</td>
<td>1.32</td>
<td>1.06</td>
<td>2.84</td>
</tr>
<tr>
<td>GR4</td>
<td>Present</td>
<td>11.50</td>
<td>105.00</td>
<td>89</td>
<td>98</td>
<td>42.60</td>
<td>1.39</td>
<td>1.12</td>
<td>1.00</td>
</tr>
<tr>
<td>GR5</td>
<td>Present</td>
<td>19.40</td>
<td>224.00</td>
<td>77</td>
<td>90</td>
<td>25.50</td>
<td>1.21</td>
<td>1.03</td>
<td>1.67</td>
</tr>
<tr>
<td>GR6</td>
<td>Present</td>
<td>36.00</td>
<td>531.00</td>
<td>64</td>
<td>88</td>
<td>38.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.12</td>
</tr>
<tr>
<td>GR3</td>
<td>High</td>
<td>8.81</td>
<td>62.40</td>
<td>90</td>
<td>98</td>
<td>17.30</td>
<td>1.40</td>
<td>1.12</td>
<td>2.46</td>
</tr>
<tr>
<td>GR4</td>
<td>High</td>
<td>9.10</td>
<td>66.90</td>
<td>90</td>
<td>98</td>
<td>16.70</td>
<td>1.40</td>
<td>1.12</td>
<td>2.55</td>
</tr>
<tr>
<td>GR5</td>
<td>High</td>
<td>11.20</td>
<td>93.30</td>
<td>86</td>
<td>95</td>
<td>15.60</td>
<td>1.35</td>
<td>1.09</td>
<td>2.73</td>
</tr>
<tr>
<td>GR6</td>
<td>High</td>
<td>13.80</td>
<td>162.00</td>
<td>92</td>
<td>104</td>
<td>15.10</td>
<td>1.44</td>
<td>1.19</td>
<td>2.82</td>
</tr>
<tr>
<td>GR3</td>
<td>Low</td>
<td>10.70</td>
<td>87.50</td>
<td>87</td>
<td>96</td>
<td>12.70</td>
<td>1.37</td>
<td>1.10</td>
<td>3.35</td>
</tr>
<tr>
<td>GR4</td>
<td>Low</td>
<td>13.60</td>
<td>158.00</td>
<td>92</td>
<td>102</td>
<td>12.00</td>
<td>1.44</td>
<td>1.17</td>
<td>3.55</td>
</tr>
<tr>
<td>GR5</td>
<td>Low</td>
<td>29.10</td>
<td>448.00</td>
<td>73</td>
<td>97</td>
<td>6.92</td>
<td>1.14</td>
<td>1.11</td>
<td>6.15</td>
</tr>
<tr>
<td>GR6</td>
<td>Low</td>
<td>8.64</td>
<td>67.50</td>
<td>95</td>
<td>139</td>
<td>7.22</td>
<td>1.49</td>
<td>1.58</td>
<td>5.90</td>
</tr>
</tbody>
</table>

$\pi$: Accident to conflict conversion factor  
CoV: Coefficient of variation  
$\hat{\lambda}$: Accident predictions  
P(X): The probability of observing the actual number of accidents based on the predictions

The results presented in Table 7.1 indicate the following:

The present definition of relevant road-user (RRU) seems to be the most appropriate definition for defining the road-user whose speed and TA-value would determine the severity of the conflict. The predictions associated with this definition were found to produce the highest probability of observing the actual number of accidents with the smallest variation around their predictions. The other alternative definitions did not perform as well as the present definition. The threshold GR6 produced the lowest overall ratio to the best. This suggests moving the present threshold to the more severe side of the TA-speed graph by 0.25 seconds.

The present definition of serious conflicts did not produce the lowest ratio to the best; however, it was among the best definitions.

Severity index approach

Eight severity indices out of the proposed forty-three were used as a predictive tool for accidents at junctions used for validating the developed conversion factors. Their definitions are presented in Table 7.2.
Table 7.2 Conflict characteristics that were used in re-scaling the conflict numbers to arrive at the investigated six severity indices.

<table>
<thead>
<tr>
<th>Severity Index</th>
<th>Conflict characteristics that constitute the index</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Conflict severity grade (S).</td>
</tr>
<tr>
<td>SC</td>
<td>Conflict severity grade (S) - conflict category (C)</td>
</tr>
<tr>
<td>SCT</td>
<td>Conflict severity grade (S) - conflict category (C) - distance separating road-users after the completion of the evasive action (TSR)</td>
</tr>
<tr>
<td>SCTA</td>
<td>Conflict severity grade (S) - conflict category (C) - distance separating road-users after the completion of the evasive action (TSR) - available time for the involved road users to see each other (ATFR) - vehicle type (V) - The sum of the numbers of traffic streams where there were road-users at the scene, which might directly interact, or might influence his behaviour, measured three seconds before the conflict (TSN3). The sum of the numbers of traffic streams where there were road-users at the scene, which might directly interact, or might influence his behaviour, measured two seconds before the conflict (TSN2). The sum of the numbers of traffic streams where there were road-users at the scene, which might directly interact, or might influence his behaviour, measured one second before the conflict (TSN1) before conflict.</td>
</tr>
<tr>
<td>N321</td>
<td>Conflict severity grade (S) - conflict category (C) - distance separating road-users after the completion of the evasive action (TSR) - available time for the involved road users to see each other (ATFR) - vehicle type (V) - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour, measured three seconds before the conflict (TSS3) sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour, measured two seconds before the conflict (TSS2) sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour, measured one second before the conflict (TSS1) before conflict.</td>
</tr>
<tr>
<td>S321</td>
<td>Conflict severity grade (S) - conflict category (C) - distance separating road-users after the completion of the evasive action (TSR) - available time for the involved road users to see each other (ATFR) - vehicle type (V) - Difference between the sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured four seconds (TSN4) and one second (TSN1) before conflict.</td>
</tr>
<tr>
<td>DS41</td>
<td>Conflict severity grade (S) - conflict category (C) - distance separating road-users after the completion of the evasive action (TSR) - available time for the involved road users to see each other (ATFR) - vehicle type (V) - Difference between the weight instant measure of exposure calculated four seconds (WSS4) and one second (WSS1) before conflict.</td>
</tr>
</tbody>
</table>

The selection of severity indices presented in Table 7.2 based on the fact that they produced the smallest variance of π compared to other proposed indices.

The results of validating the six conflict severity indices that were based on three investigated RRU definitions against the present definition of serious conflicts that are presented in Table 7.3 indicate the following:
Table 7.3  The validity of conflict definitions based on various severity indices and relevant road-user definitions for non-signalised junctions in Sweden.

<table>
<thead>
<tr>
<th>Severity index</th>
<th>Relevant road-user definition</th>
<th>Mean ( \pi ) ( 10^4 )</th>
<th>Variance ( \text{VAR} ) ( 10^{12} )</th>
<th>CoV ( \text{(%)} )</th>
<th>CoV ( \text{(%)} )</th>
<th>P(X) ( 10^{-6} )</th>
<th>CoV ( \text{(}\bar{\pi}_{i}\text{)} )</th>
<th>CoV ( \text{(}\bar{\pi}_{\text{min}}\text{)} )</th>
<th>A/B</th>
<th>I/P(X)</th>
<th>Total ratio to the best A x b x c</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Present</td>
<td>10.50</td>
<td>76.90</td>
<td>84</td>
<td>92</td>
<td>18.60</td>
<td>1.27</td>
<td>1.26</td>
<td>2.40</td>
<td>3.85</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Present</td>
<td>7.96</td>
<td>27.70</td>
<td>66</td>
<td>73</td>
<td>14.30</td>
<td>1.00</td>
<td>1.00</td>
<td>3.12</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td>SCT</td>
<td>Present</td>
<td>8.20</td>
<td>39.30</td>
<td>76</td>
<td>84</td>
<td>15.40</td>
<td>1.15</td>
<td>1.15</td>
<td>2.90</td>
<td>3.84</td>
<td></td>
</tr>
<tr>
<td>SCTA</td>
<td>Present</td>
<td>8.78</td>
<td>42.20</td>
<td>74</td>
<td>81</td>
<td>14.80</td>
<td>1.12</td>
<td>1.11</td>
<td>3.01</td>
<td>3.75</td>
<td></td>
</tr>
<tr>
<td>N321</td>
<td>Present</td>
<td>8.96</td>
<td>39.10</td>
<td>70</td>
<td>77</td>
<td>18.80</td>
<td>1.06</td>
<td>1.05</td>
<td>2.37</td>
<td>2.65</td>
<td></td>
</tr>
<tr>
<td>S321</td>
<td>Present</td>
<td>8.51</td>
<td>34.90</td>
<td>69</td>
<td>77</td>
<td>14.90</td>
<td>1.05</td>
<td>1.05</td>
<td>2.99</td>
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<td>17.00</td>
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<td>54.90</td>
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<td>91</td>
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<td>1.25</td>
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<td>97</td>
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<td>12.60</td>
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<td>1.19</td>
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<td>71</td>
<td>79</td>
<td>12.70</td>
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<td>1.08</td>
<td>3.51</td>
<td>4.09</td>
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<td>60.20</td>
<td>75</td>
<td>83</td>
<td>11.80</td>
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<td>1.14</td>
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<td>10.60</td>
<td>86.50</td>
<td>88</td>
<td>97</td>
<td>44.60</td>
<td>1.33</td>
<td>1.33</td>
<td>1.00</td>
<td>1.77</td>
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</tr>
<tr>
<td>DW41</td>
<td>Low</td>
<td>9.86</td>
<td>75.20</td>
<td>88</td>
<td>97</td>
<td>14.20</td>
<td>1.33</td>
<td>1.33</td>
<td>3.14</td>
<td>5.56</td>
<td></td>
</tr>
</tbody>
</table>

GR5  Present  19.40  224.00  77  90  25.50  1.17  1.23  1.75  2.52

\( \pi \): Accident to conflict conversion factor  
CoV: Coefficient of variation  
CoV: Average coefficient of variation  
\( \bar{\pi} \): Accident predictions  
P(X): The probability of observing the actual number of accidents based on the predictions
Generally, the introduction of the conflict severity index concept as an alternative definition of the present serious conflicts at non-signalised junctions did not provide a significant improvement. The predictions made by using any proposed indices were not as good as the predictions completed by using the present definition of serious conflicts with only one exception. DS41 produced the lowest overall ratio to the best and the highest probability of observing the actual number of accidents. It is an index that was introduced to view the conflict as a dynamic process. Conflicts were re-scaled by considering the conditions that prevailed before the evasive action was taken, including a measure of exposure that describes the complexity of the situation. It describes what happened during and after the conflicts. The severity index that was based on conflict characteristics that describe the situation where the road-user was subjected to the lowest severity “low definition of RRU” produced the lowest overall ratio to the best.

Severity index N321 based on the present definition of RRU produced the second lowest overall ratio to the best. This index is calculated based on the same characteristics that were used in calculating severity index DS41, but by considering a different measure of exposure that describes the complexity of the situation that preceded the conflicts. Instead DS41, the exposure index is calculated as a multiplication of the exposure that was measured 3, 2, and 1 seconds before the conflicts (N321).

Apart from the above two indices DS41 and N321, severity indices that were based on the present definition of RRU produced the smallest coefficient of variation of π and of the predictions. They did not produce the highest probability of observing the actual number of accidents. In fact, the results indicated that both the high definition and the present definition produced almost the same probability of observing the actual number of accidents, which were not far from the reported results for the low definition of RRU.

Conflict sub-group approach

General linear modelling was first used to define the best criteria to be adopted in selecting the conflict sub-groups that could be accident related. However, the results did not provide distinctive criteria to be used, as all the developed models were equally good. Then, the decision was made to base the selection on subjective judgement. The criteria used in forming the conflict sub-group were those perceived to reflect safety problems. For example, those conflicts of TA-value less than 0.75 seconds or conflicts involving RRU’s speed of 20km/h or conflicts in situations where there few other road-users at the junctions. The following conflict characteristics were considered while forming the investigated sub-groups that were used in the analysis:

- Conflicting speed (km/h)
- TA-value (sec)
- Instant measure of exposure defined by:
  - Number of traffic streams that might influence the involved road-users (number)
  - Sum of the road-user that might influence the involved road-users (road-users)
There are over two hundred possibilities to form conflict sub-groups using these characteristics. The sub-group selected were those that produced low variance of \( \pi \). They only were considered for further validation purposes (Table 7.4). Two types of conflict sub-groups were considered in the analysis. The first included all conflicts satisfying the selected criteria, the second type is based on the inclusion of only serious conflicts that were defined on the present threshold GR5.

**Table 7.4** The selected criteria that were used to develop conflict sub-groups.

<table>
<thead>
<tr>
<th>Sub-group</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V \geq 30 )</td>
<td>All conflicts involving a road-user at a speed of 30 km/h or more.</td>
</tr>
<tr>
<td>( V \geq 20 )</td>
<td>All conflicts involving a road-user at a speed of 20 km/h or more.</td>
</tr>
<tr>
<td>TA \leq 0.75</td>
<td>All conflicts involving a road-user that has a time to accident less than 0.75 seconds or at the collision point.</td>
</tr>
<tr>
<td>TSN124</td>
<td>All conflicts involving a road-users that interact with other road-users in at least two and not more than four traffic streams measured one second before the conflict.</td>
</tr>
<tr>
<td>TSS11</td>
<td>All conflicts involving a road-user that might be influenced by the presence of only one other road-user measured one second before the conflict.</td>
</tr>
<tr>
<td>TSS113</td>
<td>All conflicts involving a road-user that might be influenced by the presence of at least one other road-user and not more than three measured one second before the conflict.</td>
</tr>
</tbody>
</table>

The inclusion of the two last conflict sub-group (TSS13 and TSS11) instead of only one sub-group for this measure of exposure is due to the fact that few serious conflicts that are involving road-users subjected to exposure described by TS11 to form sub-group. Instead they were combined with other conflicts to form conflict sub-group TSS113.

The results of validating the selected conflict sub-group definition against the present definition of serious conflicts are presented in Table 7.5.
Table 7.5 The validity of conflict definitions based on various conflict sub-groups and relevant road-user definitions for non-signalled junctions in Sweden.

| Conflict sub-group | Relevant road-user definition | Severity | Mean \( \pi \times 10^{-6} \) | Variance \( \text{VAR} (\pi) \times 10^{-32} \) | CoV (\( \pi \)) | CoV (\( \bar{\pi} \)) | P(\( x \)) | CoV (\( \pi_{\text{min}} \)) | CoV (\( \bar{\pi}_{\text{min}} \)) | \( \frac{1}{\text{P(X)}_B} \times \text{P(X)}_C \) | Overall ratio to the best X.B.C | 
|-------------------|-------------------------------|----------|-----------------|-----------------|-----------|-------------|--------|----------------|----------------|----------------|----------------|--------|
| V\( \geq 30 \) | Present | All | 52.70 | 98400.00 | 188 | 250 | 25.06 | 4.02 | 4.05 | 1.84 | 29.99 | 
| V\( \geq 20 \) | Present | All | 15.50 | 1550.00 | 80 | 92 | 14.70 | 1.71 | 1.49 | 3.21 | 8.21 | 
| SA \( \leq 0.75 \) | Present | All | 48.50 | 50800.00 | 47 | 66 | 3.85 | 1.00 | 1.06 | 12.26 | 13.05 | 
| TSN124 | Present | All | 31.90 | 12800.00 | 112 | 145 | 41.50 | 2.39 | 2.35 | 1.14 | 6.40 | 
| TSS11 | Present | All | 24.90 | 510.00 | 91 | 110 | 30.10 | 1.94 | 1.78 | 1.57 | 5.41 | 
| V\( \geq 30 \) | Present | Serious | 78.30 | 12000.00 | 442 | 570 | 6.64 | 9.44 | 9.25 | 7.11 | 620.72 | 
| V\( \geq 20 \) | Present | Serious | 29.80 | 607.00 | 83 | 107 | 29.50 | 1.76 | 1.73 | 1.60 | 4.88 | 
| TA \( \leq 0.75 \) | Present | Serious | 57.10 | 1230.00 | 61 | 97 | 6.75 | 1.31 | 1.57 | 6.99 | 14.37 | 
| TSN124 | Present | Serious | 74.10 | 8720.00 | 126 | 161 | 16.50 | 2.69 | 2.61 | 2.86 | 20.09 | 
| TSS113 | Present | Serious | 53.70 | 861.00 | 55 | 66 | 0.12 | 1.17 | 1.08 | 410.43 | 514.83 | 
| V\( \geq 30 \) | High | All | 38.10 | 3410.00 | 153 | 199 | 15.10 | 3.27 | 3.22 | 3.13 | 32.94 | 
| V\( \geq 20 \) | High | All | 12.30 | 63.60 | 65 | 73 | 20.10 | 1.38 | 1.18 | 2.35 | 3.83 | 
| TA \( \leq 0.75 \) | High | All | 16.80 | 324.00 | 107 | 121 | 11.60 | 2.29 | 1.96 | 4.07 | 18.26 | 
| TSN124 | High | All | 28.80 | 1160.00 | 118 | 139 | 21.80 | 2.52 | 2.25 | 2.17 | 12.29 | 
| TSS11 | High | All | 20.60 | 398.00 | 97 | 108 | 12.80 | 2.07 | 1.75 | 3.69 | 13.35 | 
| V\( \geq 30 \) | High | Serious | 66.80 | 87600.00 | 443 | 571 | 7.06 | 9.46 | 9.25 | 6.69 | 585.00 | 
| V\( \geq 20 \) | High | Serious | 25.40 | 153.00 | 49 | 62 | 19.00 | 1.04 | 1.00 | 2.48 | 2.58 | 
| TA \( \leq 0.75 \) | High | Serious | 23.20 | 222.00 | 64 | 88 | 12.90 | 1.37 | 1.43 | 3.66 | 7.18 | 
| TSN124 | High | Serious | 171.00 | 1620.00 | 74 | 109 | 40.00 | 1.59 | 1.77 | 1.18 | 3.31 | 
| TSS113 | High | Serious | 21.70 | 328.00 | 83 | 96 | 14.40 | 1.78 | 1.56 | 3.28 | 9.09 | 
| TA \( \leq 0.75 \) | Low | All | 53.70 | 5950.00 | 144 | 170 | 31.50 | 3.07 | 2.76 | 1.50 | 12.69 | 
| TSN124 | Low | All | 62.30 | 4910.00 | 112 | 162 | 11.10 | 2.40 | 2.63 | 4.25 | 26.81 | 
| TSS11 | Low | All | 11.10 | 129.00 | 102 | 111 | 18.20 | 2.18 | 1.81 | 2.59 | 10.22 | 
| TA \( \leq 0.75 \) | Low | Serious | 119.00 | 26400.00 | 137 | 185 | 47.20 | 2.91 | 3.00 | 1.00 | 8.74 | 
| TSN124 | Low | Serious | 171.00 | 42200.00 | 120 | 185 | 6.18 | 2.56 | 3.00 | 7.64 | 58.74 | 
| TSS11 | Low | Serious | 24.50 | 454.00 | 87 | 102 | 19.50 | 1.86 | 1.65 | 2.42 | 7.43 | 

| GR5 | Present | 19.4 | 224.00 | 77 | 90 | 25.50 | 1.65 | 1.46 | 1.85 | 4.46 | 

\( \pi \): Accident to conflict conversion factor  
CoV: Coefficient of variation  
\( \bar{\pi} \): Accident predictions  
P(\( x \)): The probability of observing the actual number of accidents based on the predictions
Table 7.5 indicates the following:

Some conflict sub-groups produced better accident predictions than the present definition of serious conflicts as shown from their overall ratio to the best.

The lowest ratio to the best was reported for conflict sub-group $V \geq 20$. This sub-group was based on the high definition of RRU by considering only serious conflicts defined according to the present definition GR5. The RRU's was driving at a speed of at least 20km/h.

Sub-groups including only serious conflicts that were based on the high definition of RRU produced low ratio to the best. These sub-groups were associated with smaller coefficient of variation of $\pi$ and of the predictions ($\lambda$) as well as moderately high probability of observing the actual number of accidents. This was not the case if all conflicts based on the high definition of RRU were included to form these sub-groups.

Conflict sub-groups that were formed by including all conflicts (based on the present definition of RRU) produced low ratios to the best, yet not the best. The inclusion of only serious conflicts did not produce better results than those reported for sub-groups that include all conflicts satisfying the selected criterion.

Finally, conflicts sub-groups that were based on the low definition of RRU did not produce an enhancement to the present definition of serious conflicts.
Overall conclusion of verifying Hypothesis 1: three-approach comparison.

To reach an overall conclusion on the best definition of conflicts that are accident related, all results from the three approaches that were used to verify Hypothesis 1 were compared. The aim is to arrive at the most valid definition of conflicts non-signalised junctions in Sweden (Table 7.6).

**Table 7.6** The validity of conflict definitions for non-signalised junctions in Sweden based on the most valid definitions when considering each approach of analysis.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean $\pi$</th>
<th>Variance $\text{VAR} (\pi)$</th>
<th>$\text{CoV} (\pi)%$</th>
<th>$\text{CoV} (\dot{\lambda})%$</th>
<th>$P(x)$</th>
<th>$\frac{\text{CoV}(\pi)}{\text{CoV}(\dot{\lambda})}$</th>
<th>$\frac{\text{P}(X)}{\text{P}(X_{\text{max}})}$</th>
<th>Overall ratio to the best $A \times B \times C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>GR4</td>
<td>Present</td>
<td></td>
<td>11.50</td>
<td>105.00</td>
<td>89</td>
<td>98</td>
<td>42.60</td>
<td>1.89</td>
<td>1.58</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>19.40</td>
<td>224.00</td>
<td>77</td>
<td>90</td>
<td>25.50</td>
<td>1.64</td>
<td>1.45</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td></td>
<td>36.00</td>
<td>531.00</td>
<td>64</td>
<td>88</td>
<td>38.00</td>
<td>1.36</td>
<td>1.42</td>
<td>1.24</td>
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<tr>
<td>Severity Index</td>
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<td>Present</td>
<td></td>
<td>7.96</td>
<td>27.70</td>
<td>66</td>
<td>73</td>
<td>14.30</td>
<td>1.40</td>
<td>1.18</td>
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<td>8.96</td>
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<td>77</td>
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<td></td>
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<td>10.60</td>
<td>86.50</td>
<td>88</td>
<td>97</td>
<td>44.60</td>
<td>1.87</td>
<td>1.56</td>
<td>1.06</td>
</tr>
<tr>
<td>Sub-group</td>
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<td>All</td>
<td>48.10</td>
<td>508.00</td>
<td>47</td>
<td>66</td>
<td>3.85</td>
<td>1.00</td>
<td>1.06</td>
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<td></td>
<td>TSS113</td>
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<td>All</td>
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<td>1.78</td>
<td>1.57</td>
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<td></td>
<td>V ≥ 20</td>
<td>Present</td>
<td>Serious</td>
<td>29.80</td>
<td>607.00</td>
<td>83</td>
<td>107</td>
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<td>1.76</td>
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<td></td>
<td>V ≥ 20</td>
<td>High</td>
<td>All</td>
<td>12.30</td>
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<td>65</td>
<td>73</td>
<td>20.10</td>
<td>1.38</td>
<td>1.18</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>V ≥ 20</td>
<td>High</td>
<td>Serious</td>
<td>25.40</td>
<td>153.00</td>
<td>49</td>
<td>62</td>
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<td>1.04</td>
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<td>2.48</td>
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<tr>
<td></td>
<td>TA ≤ 0.75</td>
<td>Low</td>
<td>Serious</td>
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<td>264000</td>
<td>137</td>
<td>185</td>
<td>47.20</td>
<td>2.91</td>
<td>3.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

$\pi$: Accident to conflict conversion factor  
$\text{CoV}$: Coefficient of variation  
$\dot{\lambda}$: Accident predictions  
$P(X)$: The probability of observing the actual number of accidents based on the predictions

The first glance into Table 7.6 indicates that the present definition of serious conflicts could be enhanced by considering a new definition of conflicts. Threshold GR6 that was developed based on the present definition of RRU produced the lowest ratio to the best. It implies that shifting the present threshold to the left side of TA-speed graph by 0.25 seconds produced better accident prediction than those produced based on the present threshold GR5.

Conflicts sub-group $V \geq 20$ formed by including serious conflicts according to the present definition GR5 that were characterised by RRRUs' speed of at least than 20km/h produced the second lowest overall ratio to the best. It produced the smallest coefficient of variation of both $\pi$ and the average (\dot{\lambda}). The RRU definition used in determining the conflict severity of this sub-group was the high definition. Conflict sub-group $TA \leq 0.75$ based on...
the low definition of RRU produced the highest probability of observing the actual number of accidents.

The overall ratio to the best reported for severity index DS41 that was calculated based on the low definition of RRU was not far from that reported for the conflict sub-group V≥20.

Overall, the present definition of RRU was associated with better results when considering the definitions under the threshold approach, while the low and high definitions were linked to better performance if the other two approaches were investigated.

To conclude, the present definition threshold GR5 that was based on the present definition of RRU could be modified. Threshold GR6 or conflict sub-group V≥20 could be considered as alternative definitions that are expected to produce valid accident predictions at non-signalised junctions.

Finally, it is possible to conclude that the reported results for non-signalised junctions in Sweden support the verification of the sub-hypotheses 1-B, that deals with the improvement of present definition of serious conflicts. However, there is no clear-cut regarding sub-hypothesis (1-A), the threshold approach suggests different best definitions of the RRU than the conflict sub-group approach.
7.1.2 Signalised junctions in Sweden

The results of the analysis that were completed for verifying the first hypothesis at signalised junctions are presented below. However, it should be clearly stated that the reported results were based on calculating the sample variance of $\pi$ based on the observed value of $\pi$'s. Attempts were made first to estimate the variance by maximising the likelihood function (Hauer and Gårder, 1986), but the function did not converge. As an alternative, the moment method (Hauer and Gårder, 1986) was used and it produced negative values of the variance. Having negative variance for all investigated definitions makes it impossible to compare them against each other. A decision was made to revert to the sample variance method.

Threshold approach

The results of validating the tested threshold definitions as accident prediction tools are presented in Table 7.7. They indicated that the present definition of serious conflict GR5 did not produce results as good as some of the other investigated definitions.

Table 7.7 The validity of conflict definitions based on various thresholds and relevant road-user definitions for signalised junctions in Sweden.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Relevant road-user definition</th>
<th>Mean $\pi \times 10^4$</th>
<th>Variance VAR ${\pi }$ $10^{-12}$</th>
<th>CoV of $\pi$ %</th>
<th>CoV of $\hat{\lambda}$ %</th>
<th>P($x$) $10^{-01}$</th>
<th>CoV of $\pi_1$</th>
<th>CoV of $\pi_{\min}$</th>
<th>CoV of $\hat{\lambda}_1$</th>
<th>CoV of $\hat{\lambda}_{\min}$</th>
<th>$\frac{1}{P(X_i)}$ P($\hat{\lambda}_1$)</th>
<th>$\frac{1}{P(X_{\max})}$ C</th>
<th>Overall ratio to the best A x B x C</th>
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</thead>
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<td>1.93</td>
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<td>10.19</td>
<td>24.60</td>
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<td>57.60</td>
<td>62</td>
<td>16</td>
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<td>1.90</td>
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<td>53</td>
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</table>

$\pi$: Accident to conflict conversion factor
CoV: Coefficient of variation
CoV: Average coefficient of variation
$\hat{\lambda}$: Accident predictions
P($X_i$): The probability of observing the actual number of accidents based on the predictions

100
According to Table 7.7, the use of the high definition of RRU for classifying conflicts severity for the selected thresholds produced the lowest ratio to the best values. Neither the present nor the low definition of RRU produced better results than those reported for the high definition.

Table 7.7 also indicates that the threshold GR6 that intersects the x-axis of TA-speed graph at 0.25 seconds is the one that produces the lowest ratio to the best. The present threshold produced the second lowest overall ratio to the best. Its overall ratio to the best was not far from the value that was calculated for threshold GR6, particularly if the high definition of RRU was the basis for classifying the conflict severity. The probability of observing the actual number of accidents is slightly better for the threshold GR6. Thus, it is possible to suggest shifting the present threshold GR5 toward the more serious side of the speed TA-curve by 0.25 seconds.

The results in Table 7.7 indicates that regardless the type of RRU definition used in classifying conflict severity there is a tendency that the ratio to the best is getting higher as long as the threshold is shifted toward severe side of the TA-speed graph. One exception is that referred to the threshold “all”, which produced rather moderate value of the ratio to the best. In fact, it produced the smallest average coefficient of variation of the predictions. That is expected because the numbers of conflicts are higher if threshold “all” is considered.

The threshold GR6 that is established based on the low definition of RRU was the threshold that produced the highest probability of observing the actual number of accidents and the minimum coefficient of variation of π.

Severity index approach

The reported results of investigating the application of the severity index approach as a means to improve the present definition of conflicts as predictive tool for accidents are presented in Table 7.8.
Table 7.8  The validity of conflict definitions based on various severity indices and relevant road-user definitions for signalised junctions in Sweden.

<table>
<thead>
<tr>
<th>Severity index</th>
<th>Relevant road-user definition</th>
<th>Mean $\pi$ $10^{-4}$</th>
<th>Variance VAR [$\pi$]  $10^{-12}$</th>
<th>CoV $\lambda_i$ %</th>
<th>CoV $\lambda_i$ %</th>
<th>P($\pi$)</th>
<th>CoV ($\lambda_{min}$)</th>
<th>CoV ($\lambda_{min}$)</th>
<th>$\lambda_{min}$</th>
<th>P(X)</th>
<th>P(X)</th>
<th>Overall ratio to the best $A \times b \times c$</th>
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</table>

$\pi$: Accident to conflict conversion factor
CoV: Coefficient of variation
CoV: Average coefficient of variation
$\lambda$: Accident predictions
P(X): The probability of observing the actual number of accidents based on the predictions
Table 7.8 indicates the following:

None of the reported results of any severity index seemed to provide an improvement to the present definitions of serious conflicts. The present threshold GR5, that was established based on the present definition of RRU performed better than any other severity indices and reported the lowest ratio to the best.

Nevertheless, Table 7.8 suggests that indices that were developed based on high definition of RRU reported the highest probability of observing the actual number of accidents. They produced a low overall ratio to the best compared to the other indices that were defined based on the other two RRU definitions. Severity index N321, which is an attempt to describe the process of conflicts including the instant measure of exposure, was found to produce the highest probability of observing the actual number of accidents. It produced the second lowest overall ratio to the best, which is close to the reported ratio of the present threshold GR5.

**Conflict sub-group approach**

The results of validating conflict definitions under conflict sub-group approach as accident prediction tool against the present definition of serious conflicts GR5 are presented in Table 7.9.
Table 7.9 The validity of conflict definitions based on various conflict sub-groups and relevant road-user definitions for signalised junctions in Sweden.

| Conflict sub-group | Relevant road-user definition | Severity group | Mean $\pi$ 10^-6 | Variance $\sigma^2$ 10^-12 | CoV $\pi$ | CoV ($\tilde{\lambda}$) | $P(\pi)$ | CoV ($\pi_{min}$) | CoV ($\tilde{\lambda}_{min}$) | $\frac{1}{P(X|\tilde{\lambda})}$ | Overall ratio to the best A x b x c |
|--------------------|-------------------------------|----------------|-------------------|-----------------|---------|-----------------|---------|-----------------|-----------------|-----------------------------|-----------------------------|
| V\geq20            | Present                        | All            | 166.0             | 6030.00         | 47      | 68              | 7.33    | 1.32            | 2.89            | 4.77                       | 18.16                      |
| V\geq20            | Present                        | All            | 18.10             | 238.00          | 85      | 93              | 1.63    | 2.40            | 3.96            | 21.47                      | 203.78                     |
| TA \leq 0.75       | Present                        | All            | 44.50             | 266.00          | 37      | 49              | 2.76    | 1.03            | 2.08            | 12.68                      | 27.18                      |
| TSN124             | Present                        | All            | 33.90             | 309.00          | 52      | 65              | 1.14    | 1.46            | 2.79            | 30.70                      | 124.98                     |
| TSS11              | Present                        | All            | 34.50             | 401.00          | 58      | 72              | 0.64    | 1.63            | 3.06            | 54.60                      | 272.92                     |
| V\geq20            | Present                        | Serious        | 240.0             | 1830.00         | 56      | 92              | 5.99    | 1.59            | 3.93            | 5.84                       | 36.41                      |
| V\geq20            | Present                        | Serious        | 40.00             | 877.00          | 74      | 88              | 1.49    | 2.08            | 3.77            | 23.49                      | 184.59                     |
| TA \leq 0.75       | Present                        | Serious        | 54.30             | 441.00          | 39      | 54              | 5.28    | 1.09            | 2.29            | 6.63                       | 16.53                      |
| TSN124             | Present                        | Serious        | 21.90             | 147.00          | 55      | 62              | 1.52    | 1.56            | 2.63            | 23.03                      | 94.46                      |
| TSS113             | Present                        | Serious        | 77.00             | 1230.00         | 46      | 67              | 0.77    | 1.28            | 2.86            | 45.57                      | 167.11                     |
| V\geq20            | High                           | All            | 118.0             | 4790.00         | 59      | 71              | 1.46    | 1.65            | 3.05            | 23.97                      | 120.52                     |
| V\geq20            | High                           | All            | 15.10             | 125.00          | 74      | 81              | 2.34    | 2.08            | 3.46            | 14.96                      | 107.79                     |
| TA \leq 0.75       | High                           | All            | 15.60             | 63.00           | 51      | 58              | 15.60   | 1.43            | 2.48            | 2.24                       | 7.96                       |
| TSN124             | High                           | All            | 26.70             | 162.00          | 48      | 61              | 1.90    | 1.34            | 2.61            | 17.16                      | 59.95                      |
| TSS11              | High                           | All            | 26.20             | 1170.00         | 131     | 141             | 2.41    | 3.67            | 6.01            | 14.52                      | 320.47                     |
| V\geq20            | High                           | Serious        | 137.0             | 9770.00         | 72      | 114             | 35.00   | 2.03            | 4.86            | 100                        | 9.85                       |
| V\geq20            | High                           | Serious        | 33.10             | 452.00          | 64      | 75              | 6.10    | 1.81            | 3.22            | 5.74                       | 33.36                      |
| TA \leq 0.75       | High                           | Serious        | 34.10             | 147.00          | 36      | 49              | 6.49    | 1.00            | 2.11            | 5.39                       | 11.37                      |
| TSN124             | High                           | Serious        | 1                   | 1                | 11       | 1                | 1                   | 1                | 1                | 1                   | 1                      |
| TSS113             | High                           | Serious        | 28.60             | 592.00          | 85      | 96              | 6.55    | 2.39            | 4.12            | 5.34                       | 52.62                      |
| TA \leq 0.75       | Low                            | All            | 89.90             | 9930.00         | 111     | 126             | 0.13    | 3.12            | 5.40            | 261.19                     | 4394.93                    |
| TSN124             | Low                            | All            | 1                   | 1                | 11       | 1                | 1                   | 1                | 1                | 1                   | 1                      |
| TSS11              | Low                            | All            | 12.30             | 170.00          | 106     | 114             | 2.30    | 2.98            | 4.86            | 15.22                      | 220.32                     |
| TA \leq 0.75       | Low                            | Serious        | 360.0             | 68400.00        | 73      | 132             | 0.54    | 2.04            | 5.63            | 64.94                      | 746.34                     |
| TSN124             | Low                            | Serious        | 1                   | 1                | 11       | 1                | 1                   | 1                | 1                | 1                   | 1                      |
| TSS11              | Low                            | Serious        | 29.20             | 397.00          | 68      | 79              | 2.57    | 1.92            | 3.38            | 13.62                      | 88.21                      |

GR5: Present: 21.00  74.90  41  23  2.68  1.16  1.00  13.06  15.14

- $\pi$: Accident to conflict conversion factor
- CoV: Coefficient of variation
- $\tilde{\lambda}$: Accident predictions
- $P(X|\tilde{\lambda})$: The probability of observing the actual number of accidents based on the predictions
- 1) Maximum likelihood function did not converge.

Table 7.9 indicates the following:

Only three conflict sub-groups produced a lower ratio to the best than that reported for the present definition of serious conflicts.
For instance, conflict sub-group $TA \leq 0.75$ that includes all conflicts that have a TA-value of the road-user who is subject to the highest severity that does not exceed 0.75, high definition of RRU, produced the lowest overall ratio to the best. On the other hand, sub-group $TA \leq 0.75$ (high definition of RRU) that includes only serious conflicts reported the smallest coefficient of variation of $\pi$ and produced the third lowest overall ratio to the best.

The results indicate that some conflict sub-groups included only serious conflicts, which were defined according the present definition threshold GR5, and based on the high definition of RRU produced the highest probability of observing the actual number of accidents. For example conflict sub-group $V \geq 30$, which includes all serious conflicts that were determined based on the high definition of RRU and had a speed of at least 30km/h, produced the highest probability of observing the actual number of accidents. Therefore, the reported results, so far, indicate that the present definition of serious conflicts threshold GR5 could be improved by excluding some conflicts that are not accident related, such as conflicts with low speed or high TA-values.

Finally, forming conflict sub-groups based on the high definition of RRU produced the lowest ratio to the best. The other two definitions did not produce as good results as the high definition of RRU, particularly the low definition that was often associated with very low overall ratio to the best.
Overall conclusion of verifying Hypothesis 1: three-approach comparison.

To reach an overall conclusion on the best definition of conflicts that are accident related, all results reported from the three approaches that were used in verifying Hypothesis 1 were compared. The comparison was based on the most valid definitions that were reported for each approach of analysis at signalised junctions, Table 7.10.

**Table 7.10** The validity of conflict definitions for signalised junctions in Sweden based on the most valid definitions when considering each approach of analysis.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Severity group</th>
<th>Mean π $10^{-6}$</th>
<th>Variance VAR (π) $10^{12}$</th>
<th>CoV (π) %</th>
<th>CoV (λ) %</th>
<th>P(π)</th>
<th>P(λ)</th>
<th>P(X)</th>
<th>Overall ratio to the best A x b x c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>All</td>
<td></td>
<td>8.48</td>
<td>35.00</td>
<td>70</td>
<td>11</td>
<td>3.03</td>
<td>2.12</td>
<td>1.00</td>
<td>11.55</td>
</tr>
<tr>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>21.00</td>
<td>74.90</td>
<td>41</td>
<td>23</td>
<td>2.68</td>
<td>1.24</td>
<td>2.07</td>
<td>13.06</td>
</tr>
<tr>
<td>GR5</td>
<td>High</td>
<td></td>
<td>10.70</td>
<td>32.10</td>
<td>53</td>
<td>15</td>
<td>7.56</td>
<td>1.61</td>
<td>1.30</td>
<td>4.63</td>
</tr>
<tr>
<td>GR6</td>
<td>High</td>
<td></td>
<td>13.50</td>
<td>40.30</td>
<td>47</td>
<td>16</td>
<td>8.25</td>
<td>1.42</td>
<td>1.43</td>
<td>4.24</td>
</tr>
<tr>
<td>GR6</td>
<td>Low</td>
<td></td>
<td>81.10</td>
<td>695.00</td>
<td>33</td>
<td>47</td>
<td>10.90</td>
<td>1.00</td>
<td>4.20</td>
<td>3.21</td>
</tr>
<tr>
<td>Severity Index</td>
<td>SC</td>
<td>High</td>
<td>6.25</td>
<td>13.70</td>
<td>59</td>
<td>64</td>
<td>4.79</td>
<td>1.79</td>
<td>5.67</td>
<td>7.31</td>
</tr>
<tr>
<td></td>
<td>N321</td>
<td>High</td>
<td>6.69</td>
<td>13.40</td>
<td>55</td>
<td>56</td>
<td>5.90</td>
<td>1.66</td>
<td>4.96</td>
<td>5.93</td>
</tr>
<tr>
<td></td>
<td>S321</td>
<td>Low</td>
<td>10.50</td>
<td>25.90</td>
<td>48</td>
<td>54</td>
<td>2.70</td>
<td>1.47</td>
<td>4.79</td>
<td>12.96</td>
</tr>
<tr>
<td>Sub Groups</td>
<td>TA ≤ 0.75</td>
<td>Present</td>
<td>44.50</td>
<td>266.00</td>
<td>37</td>
<td>49</td>
<td>2.76</td>
<td>1.11</td>
<td>4.31</td>
<td>12.68</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td></td>
<td>15.60</td>
<td>63.00</td>
<td>51</td>
<td>58</td>
<td>15.60</td>
<td>1.54</td>
<td>5.14</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>V ≥ 30</td>
<td>Serious</td>
<td>137.00</td>
<td>977.00</td>
<td>72</td>
<td>114</td>
<td>35.00</td>
<td>2.19</td>
<td>10.07</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>34.10</td>
<td>147.00</td>
<td>36</td>
<td>49</td>
<td>6.49</td>
<td>1.08</td>
<td>4.37</td>
<td>5.39</td>
</tr>
</tbody>
</table>

π: Accident to conflict conversion factor
CoV: Coefficient of variation
CoV: Average coefficient of variation
P(π): The probability of observing the actual number of accidents based on the predictions

Table 7.10 clearly indicates that the present definition of serious conflicts could be improved by considering a new definition of RRU.

According to Table 7.10 the high definition of RRU formed the basis of the alternative definition of conflicts or severity indices that produced the lowest overall ratio to the best. This verified sub-hypothesis (1-A).

The lowest ratios to the best were reported when the threshold approach was used as a means to enhance the definition of serious conflicts. Threshold GR6 implied moving the present threshold to the left side of TA-speed graph by 0.25 seconds. It produced the lowest ratio to the best. However, the highest probability of observing the actual number of accidents was reported when accidents were related to conflict sub-group V≥30. It
includes only serious conflicts that involved road-users who are subjected to the highest severity and using a speed of at least 30km/h.

According to the result in Table 7.10, the conflict severity index approach did not provide any improvement to the present definition of serious conflicts. It could be ruled out as a means to improve the conflict definition within the Swedish TCT for this type of junction.

The results indicated that sub-hypothesis (1-A) is verified by considering an alternative of the present definition of RRU, which is the high definition. The present definition of serious conflicts could be altered by shifting the present threshold by 0.25 seconds to the left side of the TA-speed graph and sub-hypothesis (1-B) is verified.

7.1.3 Conversion factor difference due to junction type

Sub-Hypothesis (1-C): vehicle-pedestrian accident to conflict conversion factors for signalised junctions are different from those for non-signalised junctions.

The verification of this Sub-hypothesis was completed by applying the Mann-Whitney (M-W) test. The test was made for all conversion factors that were found to produce an improvement to the present definition of serious conflicts in the Swedish TCT. In addition, the conversion factors that were developed based on the present definition were tested. The results presented in Table 7.11 indicates that conversion factors developed for each type of junction are rather close to each other in their value but not in their variances. M-W test results, those were tested for significance at 5% level, showed that there are no significant differences between the tested conversion factors that could be attributed to junction type. One exception was reported for conflict sub-group TA≤0.75 based on the high definition of RRU. Accordingly, the null sub-hypothesis was generally not verified and there are similarities between conversion factors developed for each junction type.
Table 7.11  Mann-Whitney test results aimed at investigating the existence of any differences between accident to conflict conversion factors “$\pi$” developed for non-signalised and signalised junctions in Sweden.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean $\pi \times 10^6$</th>
<th>Variance VAR{$\pi$} $\times 10^{12}$</th>
<th>Mean $\pi \times 10^6$</th>
<th>Variance VAR{$\pi$} $\times 10^{12}$</th>
<th>Calculated Significant level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>19.40</td>
<td>224.00</td>
<td>21.00</td>
<td>74.90</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td></td>
<td>36.00</td>
<td>531.00</td>
<td>51.10</td>
<td>439.00</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>High</td>
<td></td>
<td>13.80</td>
<td>162.00</td>
<td>13.50</td>
<td>40.30</td>
<td>0.22</td>
</tr>
<tr>
<td>Severity index</td>
<td>N321</td>
<td>High</td>
<td></td>
<td>6.55</td>
<td>27.30</td>
<td>6.69</td>
<td>13.40</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>DS41</td>
<td>Low</td>
<td></td>
<td>10.60</td>
<td>86.50</td>
<td>11.00</td>
<td>38.10</td>
<td>0.22</td>
</tr>
<tr>
<td>Sub-Groups</td>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>All</td>
<td>16.80</td>
<td>324.00</td>
<td>15.60</td>
<td>63.00</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>V≥20</td>
<td>High</td>
<td>Serious</td>
<td>25.40</td>
<td>153.00</td>
<td>33.10</td>
<td>452.00</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Conversion factors for the most valid definitions of conflicts at each type of junction are shown above.

The results reported in Table 7.11 raised the question: Why not have one common conversion factor for all type of junctions rather than a separate conversion factor for each junction type? To answer this question a set of conversion factors were developed based on data collected from both junctions; no consideration was made for the junction type. The selected conflict definitions that were used in the following analysis were those that provided an enhancement to the present definition of conflicts for each type of junction. In addition to the present definition of serious conflicts threshold GR5 based on the present definition of RRU. The inclusion of threshold GR5 based on the high definition of RRU because it produced a low overall ratio to the best for signalised junctions in Sweden. It was not far from the threshold GR6 that produced the lowest overall ratio to the best under the threshold approach analysis for this type of junctions.

Conversion factors parameters of the selected definitions, namely the mean and variance, were estimated for both junction types together. They were used to predict the accident numbers at the junctions that were used for validation purposes and the reported results are presented in Table 7.12.
Table 7.12 The validity of conflict definitions for both junction types together based on the most valid definitions for each type of junction in Sweden.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean $\pi$</th>
<th>Variance $\lambda$</th>
<th>CoV $\lambda$</th>
<th>CoV $\pi$</th>
<th>$P(\lambda)$</th>
<th>$1 - P(\lambda)$</th>
<th>Overall ratio to the best A x b x c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>GR5 Present</td>
<td>17.10</td>
<td>215.00</td>
<td>86</td>
<td>98</td>
<td>0.07</td>
<td>1.12</td>
<td>1.02</td>
<td>4.13</td>
<td>4.71</td>
</tr>
<tr>
<td></td>
<td>GR6 Present</td>
<td>38.30</td>
<td>862.00</td>
<td>77</td>
<td>96</td>
<td>0.16</td>
<td>1.00</td>
<td>1.00</td>
<td>1.86</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>GR5 High</td>
<td>9.10</td>
<td>75.00</td>
<td>95</td>
<td>104</td>
<td>0.19</td>
<td>1.23</td>
<td>1.08</td>
<td>1.52</td>
<td>2.03</td>
</tr>
<tr>
<td></td>
<td>GR6 High</td>
<td>11.60</td>
<td>118.00</td>
<td>94</td>
<td>104</td>
<td>0.18</td>
<td>1.22</td>
<td>1.08</td>
<td>1.62</td>
<td>2.15</td>
</tr>
<tr>
<td>Severity Index</td>
<td>N321 High</td>
<td>5.32</td>
<td>24.50</td>
<td>93</td>
<td>101</td>
<td>0.16</td>
<td>1.21</td>
<td>1.05</td>
<td>1.80</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>DS41 Low</td>
<td>10.70</td>
<td>129.00</td>
<td>106</td>
<td>116</td>
<td>0.03</td>
<td>1.38</td>
<td>1.21</td>
<td>8.59</td>
<td>14.3</td>
</tr>
<tr>
<td>Sub-Grouping</td>
<td>TA $\leq$ 0.75</td>
<td>High</td>
<td>All</td>
<td>14.20</td>
<td>207.00</td>
<td>102</td>
<td>114</td>
<td>0.29</td>
<td>1.32</td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td>V$\geq$30 High</td>
<td>Serious</td>
<td>97.50</td>
<td>7460.0</td>
<td>81</td>
<td>113</td>
<td>0.02</td>
<td>1.05</td>
<td>1.18</td>
<td>14.41</td>
</tr>
<tr>
<td></td>
<td>V$\geq$20 High</td>
<td>Serious</td>
<td>27.70</td>
<td>523.00</td>
<td>83</td>
<td>96</td>
<td>0.08</td>
<td>1.08</td>
<td>1.00</td>
<td>3.55</td>
</tr>
</tbody>
</table>

$\pi$: Accident to conflict conversion factor  
CoV: Coefficient of variation  
$\lambda$: Accident predictions  
$P(\lambda)$: The probability of observing the actual number of accidents based on the predictions

Table 7.12 indicates the following:

The estimated mean and variance for the both junction types together are generally smaller than the variances reported earlier for non-signalled junction and larger than the variance reported for signalised junctions.

The present definition of serious conflicts did not provide the lowest ratio to the best.

The most valid definitions of conflict that could be used as accident prediction tool are usually those based on the high definition of RRU. However, threshold GR6 based on the present definition of RRU, which was reported earlier, produced the lowest overall ratio to the best for non-signalled junctions in Sweden. It produced the second lowest overall ratio to the best for both junction types together.

The lowest overall ratio to the best was reported for conflict sub-group TA $\leq$ 0.75. This was based on the high definition of RRU and by including all conflicts that have a TA-value of the road-user who is subject to the highest severity that does not exceed 0.75. Conflict sub-group TA $\leq$ 0.75 earlier produced the lowest overall ratio to the best for signalised junctions in Sweden.

Predictions based on both junction types together conversion factors

A comparison between predictions based on the conversion factors developed for both junction types together with those made based on factors developed for each type of junctions are presented in Table 7.13. Conversion factors that produced the lowest ratio
to the best for both junction type together were utilised for this comparison. In addition, predictions made based on the present definition of serious conflict were also included.

**Table 7.13** Comparison between accident predictions made for each type of junction based on conversion factors developed for each individual type of junction in Sweden with predictions based on conversion factors developed for both junction types together.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Non-signalised junctions</th>
<th>Signalised junctions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Predictions made based on both junctions conversion factors</td>
<td>Predictions made based on non-signalised junctions conversion factors</td>
</tr>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td></td>
<td>77</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>High</td>
<td></td>
<td>95</td>
<td>105</td>
</tr>
<tr>
<td>Severity Index</td>
<td>N321</td>
<td>High</td>
<td></td>
<td>93</td>
<td>101</td>
</tr>
<tr>
<td>Sub-group</td>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>All</td>
<td>102</td>
<td>115</td>
</tr>
</tbody>
</table>

π: Accident to conflict conversion factor  
CoV: Coefficient of variation  
λ̂: Accident predictions  
P(λ̂): The probability of observing the actual number of accidents based on the predictions

According to Table 7.13 accidents could be better predicted at non-signalised junction by using conversion factors developed for both junctions types together. The probability of observing the actual number of accidents is higher for both junction types together. It (P(λ̂)) is believed to be the most important indicator for validating any definition. However, coefficients of variation of the predictions were slightly higher than those reported for non-signalised junction factors.

Interestingly and based on conversion factors developed for both junction types together, threshold GR6 produced the highest probability of observing the actual number of accidents and the smallest coefficient of variation of π and second smallest coefficient of variation of the predictions. Thus, the overall ratio to the best for this threshold is almost one, which means that such conversion factors meet all the conditions that are needed to validate conflict definition for accident prediction purposes.

The results at signalised junctions provide different indications. For instance, the probability of observing the actual number of accidents was slightly higher in the case of utilising the conversion factors developed for this type of junction. In contrast to the results reported for non-signalised junctions, the coefficients of variations were much higher in case of using conversion factors that were developed for both junction types together. Further, conflict-sub-group TA ≤ 0.75, which reported the lowest overall ratio to
the best based on conversion factors developed for both junction types together, produced the highest probability of observing the actual number of accidents but it did not produce the smallest coefficient of variation of the prediction. This was also the case with conversion factors based on conflict definitions developed for signalised junctions. For instance, conflict-sub-group TA≤0.75 produced the highest probability of observing the actual number of accidents. It produced the second lowest overall ratio to the best for signalised junctions, but not the smallest coefficient of variation of π or the smallest coefficient of variation of the predictions.

To sum up, considering common conversion factors for both junction types together was found to produce good predictions for accidents at non-signalised junction but not for accidents at signalised junctions.
Conclusions

- The present definition of serious conflicts in the Swedish TCT could be modified by considering either an alternative definition of RRU or alternative definitions of what constitute conflicts that are accident related.

- The reported results indicate that the suggested modification would differ whether the junction has signal control or not.

- The present definition of the RRU formed the basis for the most valid definition of conflicts for non-signalised junctions. It was the high definition of RRU that formed the basis for the most valid definitions of conflicts for signalised junctions.

- Threshold GR6 was the most valid definition of conflict for both non-signalised and non-signalised junctions. Serious conflicts produced the most valid accident predictions are all conflicts that are located above the threshold that intersect the X-axis of TA-speed graph at 0.25 seconds.

- Overall, some of the conflict definitions that were investigated under the threshold approach theme were the most valid definitions as accident prediction tool for each type of junction. The investigated definitions under conflict sub-group approach provided reasonable predictions. On the other hand, conflict definitions under severity index approach did not provide results that were as good as those reported for other definitions.

- The developed conversion factors were not found to be statistically different for junction types (signalised and non-signalised).

- The most valid definition of serious conflicts for both junction types together was conflict sub-group TA ≤ 0.75, which was formed based on the high definition of RRU. It produced the highest probability of observing the actual number of accidents and the lowest overall ratio to the best. Threshold GR6 based on the present definition produced the second lowest overall ratio to the best. Severity index N321 provides reasonable accident predictions.

- Considering one conversion factor for both junction types together produced good accident predictions for non-signalised junctions but not for signalised junctions.
7.2 The application of the Swedish TCT in Jordan

Hypothesis 2: The improved Swedish traffic conflicts technique can also be applied in Jordan

Two sub-hypotheses were formulated under this hypothesis.

Sub-hypothesis (2-A): Conflict definitions that are valid for accident predictions in Sweden are not valid in Jordan.

Sub-hypothesis (2-B): Accident predictions for junctions in Jordan made by using conversion factors developed in Sweden are not as good as the predictions made based on factors developed in Jordan.

To be able to verify these two sub-hypotheses, conversion factors based on data collected from Jordan were estimated. The same approach of analysis used in verifying the first hypothesis was used regarding the inclusion of RRU definitions and analysis approaches. However, a decision was made to consider only two alternative definitions of RRU, namely the present and the high definition. This was due to the fact that the low definition of RRU was not adding any improvement to the present definition of conflicts. All alternative conflict definitions that are related to this definition were not included. In addition, the “all” threshold was not considered in the analysis for the same reason.

7.2.1 Non-signalised junctions in Jordan

Threshold approach

The results of validating the Swedish TCT in Jordan at non-signalised junctions were completed by considering the proposed alternative thresholds that separate serious conflicts from non-serious conflicts are presented in Table 7.14.
Table 7.14 The validity of conflict definitions based on various thresholds and relevant road-user definitions for non-signalised junctions in Jordan.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Relevant road-user definition</th>
<th>Mean $\pi$ $\times 10^6$</th>
<th>Variance $\text{VAR} [\pi]$ $\times 10^{12}$</th>
<th>CoV $\pi$</th>
<th>CoV ((\lambda_1)) $\times 10^{-3}$</th>
<th>P(x)</th>
<th>CoV ((\pi_{\text{min}}))</th>
<th>CoV ((\lambda_{1_{\text{min}}})) A</th>
<th>CoV ((\lambda_{1_{\text{min}}})) B</th>
<th>(\frac{1}{\text{P}(X)})</th>
<th>(\frac{\text{P}(X_i)}{\text{P}(X_{\max})})</th>
<th>Overall ratio to the best A x b x c</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR3</td>
<td>Present</td>
<td>1.89</td>
<td>0.80</td>
<td>47</td>
<td>56</td>
<td>2.20</td>
<td>1.24</td>
<td>1.22</td>
<td>4.86</td>
<td>4.86</td>
<td>7.32</td>
<td>7.32</td>
</tr>
<tr>
<td>GR4</td>
<td>Present</td>
<td>2.12</td>
<td>1.94</td>
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<td>2.13</td>
<td>1.74</td>
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<td>5.02</td>
<td>5.02</td>
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<tr>
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<td>Present</td>
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<td>8.03</td>
<td>70</td>
<td>81</td>
<td>6.78</td>
<td>1.84</td>
<td>1.76</td>
<td>1.58</td>
<td>1.58</td>
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</tr>
<tr>
<td>GR6</td>
<td>Present</td>
<td>6.52</td>
<td>35.10</td>
<td>91</td>
<td>104</td>
<td>10.70</td>
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<tr>
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<td>0.81</td>
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<tr>
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<td>*</td>
<td>*</td>
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<td>*</td>
<td>*</td>
<td>*</td>
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</tr>
</tbody>
</table>

\(\pi\): Accident to conflict conversion factor
CoV: Coefficient of variation
\(\lambda\): Accident predictions
P(X): The probability of observing the actual number of accidents based on the predictions

Table 7.14 indicates the following:

The overall ratio to the best of the present definition of serious conflict GR5 was one of the lowest ratios. Moreover, the definitions that were based on the present definition of RRU produced rather a high probability of observing the actual number of accidents. In fact, the highest probability of observing the actual number of accidents was reported for threshold GR6, which was based on the present definition of RRU.

The lowest ratio to the best was reported for the threshold GR3, which was based on the high definition of RRU. This also produced the smallest coefficient of variation of \(\pi\) and the average of the predictions \(\lambda\). However, the difference between the overall ratio to the best reported for the present threshold GR5, which is based on the present definition of RRU, is rather small. The present threshold produced the second highest probability of observing the actual number of accidents. Therefore, one should be cautious before concluding that the threshold GR3 is the most valid definition and excluding the present threshold GR5.

In general, thresholds based on the high definition of RRU produced small coefficients of variation of \(\pi\) and the average of the predictions \(\lambda\), but not a high probability of observing the actual number of accidents. On the other hand, thresholds (GR5, GR6) based on the present definition of RRU produced high probability of observing the actual number of accidents but not small coefficients of variation of \(\pi\) or the average of the predictions \(\lambda\).
Severity index Approach:

The results of validating the definitions under conflict severity indices are presented in Table 7.15. They suggest that some of the proposed indices provide better accident predictions than those reported if the present definition of serious conflicts is used. Still, the present definition of serious conflicts reported the highest probability of observing the actual number of accidents.

Table 7.15  The validity of conflict definitions based on various severity indices and relevant road-user definitions for non-signalised junctions in Jordan.

| Severity Index | Relevant road-user definition | Mean $\pi^{10^6}$ | Variance $\text{VAR}(\pi)$ $10^{12}$ | CoV $\pi$ % | CoV $\lambda_1$ % | P($\pi$) | P($\lambda_1$) | CoV $\pi_{\min}$ | P($\pi_{\min}$) | CoV $\lambda_{\min}$ | P($\lambda_{\min}$) | $\frac{P(X)}{P(X_{\text{max}})}$ | Overall ratio to the best Ax b xc |
|----------------|--------------------------------|-------------------|-------------------------------|-------------|-----------------|--------|--------------|-----------------|----------------|----------------|----------------|----------------|----------------|-----------------|
| S              | Present                        | 2.08              | 0.84                          | 44          | 53              | 3.10   | 1.33         | 1.29            | 2.19           | 3.77           |                |                 |                  | 5.79            |
| SC             | Present                        | 1.50              | 0.73                          | 54          | 64              | 2.99   | 1.64         | 1.56            | 2.27           | 5.83           |                |                 |                  | 11.99           |
| SCT            | Present                        | 1.65              | 0.80                          | 54          | 62              | 2.88   | 1.64         | 1.51            | 2.35           | 5.83           |                |                 |                  | 7.28            |
| SCTA           | Present                        | 1.59              | 0.80                          | 56          | 64              | 2.65   | 1.70         | 1.56            | 2.56           | 6.78           |                |                 |                  | 10.38           |
| N321           | Present                        | 1.39              | 0.86                          | 67          | 75              | 2.10   | 2.03         | 1.83            | 3.23           | 11.99          |                |                 |                  | 7.28            |
| S321           | Present                        | 1.40              | 0.79                          | 63          | 71              | 2.16   | 1.91         | 1.73            | 3.14           | 10.38          |                |                 |                  | 10.38           |
| DS41           | Present                        | 1.58              | 1.10                          | 66          | 74              | 3.81   | 2.00         | 1.80            | 1.78           | 6.43           |                |                 |                  | 6.43            |
| DW41           | Present                        | 1.50              | 0.86                          | 62          | 69              | 3.74   | 1.88         | 1.68            | 1.81           | 5.73           |                |                 |                  | 5.73            |
| S              | High                           | 1.56              | 0.27                          | 33          | 41              | 2.67   | 1.00         | 1.00            | 2.54           | 2.54           |                |                 |                  | 2.54            |
| SC             | High                           | 1.13              | 0.34                          | 51          | 58              | 2.64   | 1.55         | 1.41            | 2.57           | 5.61           |                |                 |                  | 5.61            |
| SCT            | High                           | 1.18              | 0.40                          | 53          | 60              | 2.19   | 1.61         | 1.46            | 3.10           | 7.28           |                |                 |                  | 7.28            |
| SCTA           | High                           | 1.21              | 0.47                          | 56          | 63              | 2.20   | 1.70         | 1.54            | 3.08           | 8.04           |                |                 |                  | 8.04            |
| N321           | High                           | 1.02              | 0.39                          | 61          | 70              | 1.62   | 1.85         | 1.71            | 4.19           | 13.21          |                |                 |                  | 13.21           |
| S321           | High                           | 1.00              | 0.31                          | 56          | 63              | 1.99   | 1.70         | 1.54            | 3.41           | 8.88           |                |                 |                  | 8.88            |
| DS41           | High                           | 1.19              | 0.39                          | 52          | 59              | 3.35   | 1.58         | 1.44            | 2.02           | 4.59           |                |                 |                  | 4.59            |
| DW41           | High                           | 1.12              | 0.33                          | 52          | 58              | 3.41   | 1.58         | 1.41            | 1.99           | 4.43           |                |                 |                  | 4.43            |

GR5 Present | 4.02 | 8.03 | 70 | 81 | 6.78 | 2.12 | 1.98 | 1.00 | 4.19 |

$\pi$: Accident to conflict conversion factor
CoV: Coefficient of variation
$\lambda$: Accident predictions
P($\pi$): The probability of observing the actual number of accidents based on the predictions

According to Table 7.15 severity indices that were based on the high definition of RRU were found to provide lower overall ratio to the best than those indices that were based on the present definition of RRU.
Conflict severity index $S$ considers re-scaling the conflicts according to their severity. It produced the lowest overall ratio to the best and the smallest coefficient of variation of $\pi$ and average coefficient of variation of the predictions.
Conflict Sub-group approach

The results of validating conflict sub-groups as accident prediction tools for non-signalised junctions in Jordan are presented in Table 7.16.

Table 7.16  The validity of conflict definitions based on various conflict sub-groups and relevant road-user definitions for non-signalised junctions in Jordan.

<table>
<thead>
<tr>
<th>Conflict sub-group</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean π 10^4</th>
<th>Variance VAR(π) 10^12</th>
<th>CoV (π) %</th>
<th>CoV (λ) %</th>
<th>CoV(πmin) A</th>
<th>CoV(λmin) B</th>
<th>P(Xi)</th>
<th>P(Xmax)</th>
<th>Overall ratio to the best A x b x c</th>
</tr>
</thead>
<tbody>
<tr>
<td>V≥30</td>
<td>Present</td>
<td>All</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>V≥20</td>
<td>Present</td>
<td>All</td>
<td>5.76</td>
<td>23.10</td>
<td>83</td>
<td>103</td>
<td>22.20</td>
<td>4.35</td>
<td>2.83</td>
<td>1.44</td>
<td>17.70</td>
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<tr>
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<td>All</td>
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<td>1.99</td>
<td>34</td>
<td>49</td>
<td>3.78</td>
<td>1.75</td>
<td>1.34</td>
<td>8.44</td>
<td>19.82</td>
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<tr>
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<td>All</td>
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<td>30.90</td>
<td>125</td>
<td>155</td>
<td>0.44</td>
<td>6.50</td>
<td>4.26</td>
<td>71.85</td>
<td>1989.5</td>
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<td>84</td>
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<td>3.61</td>
<td>2.31</td>
<td>9.76</td>
<td>81.50</td>
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<td>Serious</td>
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<td>—</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>V≥20</td>
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<td>Serious</td>
<td>11.20</td>
<td>86.00</td>
<td>83</td>
<td>106</td>
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<td>12.62</td>
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<td>TA ≤ 0.75</td>
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<td>5.57</td>
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<td>98</td>
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<tr>
<td>V≥20</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td>1.00</td>
<td>—</td>
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<tr>
<td>TA ≤ 0.75</td>
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<td>All</td>
<td>2.26</td>
<td>1.78</td>
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<td>68</td>
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<td>13.80</td>
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<td>66</td>
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<td>2.29</td>
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</table>

π: Accident to conflict conversion factor  
CoV: Coefficient of variation  
CoV: Average coefficient of variation  
λ: Accident predictions  
P(Xi): The probability of observing the actual number of accidents based on the predictions  
1) Maximum likelihood function did not converge.
The results illustrate the following:

The overall ratio to the best reported for some of conflict sub-groups were lower than the reported ratio for the present definition of serious conflicts in the present Swedish TCT.

The lowest overall ratio to the best was reported for conflict sub-group V≥20, which was based on the high definition of RRU. This conflict sub-group (V≥20) includes all serious conflicts that were defined according to the present definition GR5 and involving road-users travelling at a speed of 20km/h or more. The estimated coefficient of variation of \( \pi \) for this sub-group and the average coefficient of variation of the predictions, were the smallest among other alternative sub-group definitions. Conflict sub-groups that were formed by considering all conflicts based on the high definition of RRU produced a small coefficient of variation of \( \pi \) and its average coefficient of variation of the predictions, excluding conflict sub-group V≥20.

The probability of observing the actual number of accidents was higher when the present definition of RRU was used in classifying the severity of conflicts. The highest probability was reported for conflict sub-group V≥20 that includes only serious conflicts in the sub-group.

**Overall conclusion of verifying Hypothesis 1: three-approach comparison.**

Only definitions that were found as the most valid definitions for accident predictions at non-signalised junction were used for the overall comparison; the reported results in Table 7.17 indicate the following:

**Table 7.17** The validity of conflict definitions for non-signalised junctions in Jordan based on the most valid definitions when considering each approach of analysis.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean ( \pi )</th>
<th>Variance ( \text{VAR}(\pi) )</th>
<th>CoV(( \pi )) %</th>
<th>CoV(( \lambda )) %</th>
<th>P(( \pi ))</th>
<th>CoV(( \lambda_{\text{min}} ))</th>
<th>CoV(( \lambda_{\text{min}} )) B</th>
<th>( \frac{1}{P(X)} )</th>
<th>Overall ratio to the best A x b x c</th>
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<td>41</td>
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<tr>
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<td>Serious</td>
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<td>86.00</td>
<td>83</td>
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<td>1.00</td>
<td>1.00</td>
<td>7.33</td>
<td>7.33</td>
</tr>
</tbody>
</table>

\( \pi \): Accident to conflict conversion factor

\( \text{CoV} \): Coefficient of variation

\( \lambda \): Accident predictions

\( P(X) \): The probability of observing the actual number of accidents based on the predictions
First, conflict definitions that were based on the high definition of RRU reported the lowest overall ratio to the best.

Second, the lowest overall ratio to the best was reported for conflict sub-group (V≥20) that includes serious conflicts that were defined based on the high definition of RRU. Serious conflicts were defined based on the present definition GR5. Definitions under conflict sub-group approach produced the lowest overall ratio to the best among other definitions.

Conflict definitions based on the threshold approach alone, including the present definition of serious conflicts, produced the highest values of the overall ratio to the best.

Comparison between valid definitions in the two countries

Verification of Sub-Hypothesis (2-A)

Conflict definitions that were proven to be valid for accident prediction purposes in each country are presented in Table 7.18 in conjunction with their accident to conflict conversion factor values and their variances and their overall ratio to the best.

Table 7.18 Accident to conflict conversion factors “πs” based on conflict definitions that were proven to be valid for accident prediction purposes for non-signalised junctions in each country.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Country where it has high validity</th>
<th>Sweden Mean</th>
<th>Sweden Variance VAR(π)</th>
<th>Sweden Overall ratio to the best</th>
<th>Jordan Mean</th>
<th>Jordan Variance VAR(π)</th>
<th>Jordan Overall ratio to the best</th>
<th>Calculated Significant level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td></td>
<td>19.40</td>
<td>224.00</td>
<td>4.40</td>
<td>4.02</td>
<td>8.03</td>
<td>39.00</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td>Sweden</td>
<td></td>
<td>36.00</td>
<td>531.00</td>
<td>2.40</td>
<td>6.52</td>
<td>35.10</td>
<td>41.25</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>GR3</td>
<td>High</td>
<td>Jordan</td>
<td></td>
<td>8.81</td>
<td>62.40</td>
<td>8.26</td>
<td>1.69</td>
<td>0.42</td>
<td>33.39</td>
<td>0.79</td>
</tr>
<tr>
<td>Severity Index</td>
<td>S</td>
<td>High</td>
<td>Jordan</td>
<td></td>
<td>8.40</td>
<td>55.70</td>
<td>7.99</td>
<td>1.56</td>
<td>0.27</td>
<td>23.15</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>DS41</td>
<td>Low</td>
<td>Sweden</td>
<td></td>
<td>10.60</td>
<td>86.50</td>
<td>3.10</td>
<td>3)</td>
<td>3)</td>
<td>3)</td>
<td>3)</td>
</tr>
<tr>
<td>Sub-group</td>
<td>V≥20</td>
<td>High</td>
<td>Serious</td>
<td>Sweden &amp; Jordan</td>
<td>25.40</td>
<td>153.00</td>
<td>2.58</td>
<td>4.36</td>
<td>0.70</td>
<td>7.33</td>
<td>0.57</td>
</tr>
</tbody>
</table>

1) The validity is based on the results of this study.
2) Overall ratio to the best is the calculated ratio for the proposed definition in relation to all other definition proposed in each country.
3) Severity index DS41 based on the low definition of RRU was not included in the analysis for junctions in Jordan.

According to Table 7.18, Conversion factors estimated for non-signalised junctions in Jordan were lower in their values and variances than in Sweden. Nevertheless, Mann-Whitney test indicated that there are no significant differences between conversion factors developed in each country. Still they performed differently as accident prediction tools. Table 7.18 indicates that the definitions that were valid in Sweden were different from the valid definitions in Jordan. Few exceptions were reported, one is conflict sub-group V≥20,
which performed well in both countries. The threshold GR6 reported one of the lowest overall ratios to the best for non-signalised junctions, but to a lesser degree. The reported results at non-signalised junctions verified the Sub-hypothesis (1-A), but with few exceptions.

Prediction differences due to country

Verifying Sub-Hypothesis (2-B)

The verification of Sub-hypothesis (2-B) was also completed by comparing the predictions made for non-signalised junctions in Jordan based on conversion factors that were proven to be the most valid tool in each country. The validity of accident predictions for signalised junctions in Jordan based on the most valid definitions of conflicts in each country are presented in Table 7.19. The reported overall ratios to the best in Table 7.19 are not equal to those presented in Table 7.18, which were corresponding to the predictions made for non-signalised junctions in each country. Nonetheless, they provided similar trends.

The predictions based on conversion factors developed in Sweden provided higher coefficients of variations of the predictions than those based on conversion factors developed in Jordan (Table 7.19). Predictions based on definitions under the threshold approach produced lower probability of observing the actual number of accidents. They provide a higher probability of observing actual number of accidents if definitions under the other two approaches were considered, namely, the severity index and the sub-group.

Table 7.19 Comparison between accident predictions made for non-signalised junctions in Jordan based on conversion factors developed in each country for the most valid definitions of conflicts.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Predictions based on factors developed for non-signalised junctions in Sweden</th>
<th>Predictions based on factors developed for non-signalised junction in Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CoV (π) %</td>
<td>CoV (λ) %</td>
</tr>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td></td>
<td>64</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>GR3</td>
<td>High</td>
<td></td>
<td>90</td>
<td>96</td>
</tr>
<tr>
<td>Severity Index</td>
<td>S</td>
<td>High</td>
<td></td>
<td>89</td>
<td>98</td>
</tr>
<tr>
<td>Sub-group</td>
<td>V≥20</td>
<td>High</td>
<td>Serious</td>
<td>49</td>
<td>62</td>
</tr>
</tbody>
</table>

π: Accident to conflict conversion factor  
CoV: Coefficient of variation  
CoV: Average coefficient of variation  
λ: Accident predictions  
P(x): The probability of observing the actual number of accidents based on the predictions
It is possible to conclude that the predictions based on conversion factors developed in Sweden (by considering definitions under the threshold approach) were not as good as those in Jordan. Predictions based on conflict sub-group V≥20 conversion factor in Sweden produced a high probability of observing the actual number of accidents but with a higher variation when compared to Jordan. It is possible to conclude that Hypothesis (2-B) is verified for this type of junctions.

7.2.2 Signalised junctions in Jordan

Threshold approach

Validating conflict definitions concerning the threshold approach for signalised junctions in Jordan provides similar results to those reported for the non-signalised junctions. The results of validation that are presented in Table 7.20 indicate the following:

The high definition of RRU produced the lowest overall ratio to the best. Thresholds based on this definition produced small coefficients of variation of \( \pi \) and the average of the predictions \( \hat{\lambda} \) but not a high probability of observing the actual number of accidents. On the other hand, thresholds based on the present definition of RRU produced a high probability of observing the actual number of accidents but not small coefficients of variation of \( \pi \) or the average of the predictions \( \hat{\lambda} \).

### Table 7.20

The validity of conflict definitions based on various thresholds and relevant road-user definitions for signalised junctions in Jordan.

| Threshold | Relevant road-user definition | Mean \( \pi \times 10^{-6} \) | Variance VAR \{ \pi \} \times 10^{12} | CoV \( \pi \) | CoV \( \hat{\lambda} \) | \( P(\pi) \times 10^{-3} \) | \( \frac{CoV(\pi)}{CoV(\pi_{min})} \) \( \Lambda \) | \( \frac{CoV(\hat{\lambda})}{CoV(\hat{\lambda}_{min})} \) \( B \) | \( \frac{1}{\frac{P(X_{min})}{P(X_{max})}} \) C | Overall ratio to the best \( A \times b \times c \) |
|-----------|-------------------------------|-----------------------------|-----------------------------------|-------------|-----------------|------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-----------------------------|
| GR3       | Present                        | 4.45                        | 1.29                             | 26          | 31              | 3.75              | 1.04                           | 1.03                            | 2.66                            | 2.85                          | 4.20                        |
| GR4       | Present                        | 4.96                        | 2.48                             | 32          | 38              | 4.00              | 1.28                           | 1.27                            | 2.49                            | 4.04                          | 4.45                        |
| GR5       | Present                        | 6.65                        | 8.20                             | 43          | 51              | 6.55              | 1.72                           | 1.70                            | 1.52                            | 4.45                          | 5.00                        |
| GR6       | Present                        | 11.50                       | 41.20                            | 56          | 67              | 9.96              | 2.24                           | 2.23                            | 1.00                            | 5.00                          | 6.00                        |
| GR3       | High                           | 4.19                        | 1.11                             | 25          | 30              | 3.64              | 1.00                           | 1.00                            | 2.74                            | 2.74                          | 4.45                        |
| GR4       | High                           | 4.24                        | 1.17                             | 26          | 31              | 3.85              | 1.04                           | 1.03                            | 2.59                            | 2.78                          | 4.45                        |
| GR5       | High                           | 4.58                        | 1.92                             | 30          | 36              | 4.22              | 1.20                           | 1.20                            | 2.36                            | 3.40                          | 4.45                        |
| GR6       | High                           | 5.42                        | 3.48                             | 34          | 40              | 4.43              | 1.36                           | 1.33                            | 2.25                            | 4.08                          | 4.45                        |

\( \pi \): Accident to conflict conversion factor  
CoV: Coefficient of variation  
\( \hat{\lambda} \): Accident predictions  
\( P(X_i) \): The probability of observing the actual number of accidents based on the predictions

The results presented in Table 7.20 also indicated that the threshold GR3 (based on the high definition of RRU) was found to produce the lowest overall ratio to the best. The smallest coefficients of variations of \( \pi \) and the average coefficient of variation of the
prediction were reported for threshold GR3. This implies shifting the present threshold GR5 to the right towards the less severe side of the TA-speed graph by 0.5 seconds. However, it should be noted that the differences in the overall ratio to the best for the thresholds GR3, GR4, and GR5, which are based on the high definition of RRU, are small.

The present definition of serious conflicts, threshold GR5 did not produce a low overall ratio to the best, even though they produced a high probability of observing the actual number of accidents. In fact, the threshold GR6 (based on the present definition of RRU) reported the highest probability of observing the actual number of accidents.

Severity index approach

The results of validating definitions under conflict severity index approach, which are presented in Table 7.21, indicate that these definitions produced similar results to those reported for the present definition of serious conflicts, threshold GR5. The overall ratios to the best for all investigated indices are almost equal indicating a small difference in their performance as accident prediction tools.
Table 7.21  The validity of conflict definitions based on various severity indices and relevant road-user definitions for signalised junctions in Jordan.

<table>
<thead>
<tr>
<th>Severity index</th>
<th>Relevant road-user definition</th>
<th>Mean $\pi \times 10^{-6}$</th>
<th>Variance $\text{VAR} { \pi } \times 10^{-12}$</th>
<th>$\text{CoV} (\pi)$</th>
<th>$\text{CoV} (\dot{\lambda})$</th>
<th>$P(\pi)$</th>
<th>$\frac{\text{CoV} (\pi_{\min})}{\lambda_{\min}}$</th>
<th>$\frac{\text{CoV} (\dot{\lambda}_{\min})}{B}$</th>
<th>$\frac{1}{P(X_{ij})}$</th>
<th>$\frac{P(X_{ij})}{P(X_{max})}$</th>
<th>Overall ratio to the best $A \times B \times C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Present</td>
<td>4.33</td>
<td>2.91</td>
<td>39</td>
<td>45</td>
<td>4.39</td>
<td>1.30</td>
<td>1.32</td>
<td>1.49</td>
<td>2.57</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Present</td>
<td>3.43</td>
<td>1.30</td>
<td>33</td>
<td>38</td>
<td>4.73</td>
<td>1.10</td>
<td>1.12</td>
<td>1.38</td>
<td>1.70</td>
<td></td>
</tr>
<tr>
<td>SCT</td>
<td>Present</td>
<td>3.55</td>
<td>1.65</td>
<td>36</td>
<td>41</td>
<td>4.87</td>
<td>1.20</td>
<td>1.21</td>
<td>1.34</td>
<td>1.95</td>
<td></td>
</tr>
<tr>
<td>SCTA</td>
<td>Present</td>
<td>3.70</td>
<td>1.94</td>
<td>38</td>
<td>43</td>
<td>4.70</td>
<td>1.27</td>
<td>1.26</td>
<td>1.39</td>
<td>2.23</td>
<td></td>
</tr>
<tr>
<td>N321</td>
<td>Present</td>
<td>3.44</td>
<td>1.83</td>
<td>39</td>
<td>44</td>
<td>3.95</td>
<td>1.30</td>
<td>1.29</td>
<td>1.66</td>
<td>2.79</td>
<td></td>
</tr>
<tr>
<td>S321</td>
<td>Present</td>
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<td>1.62</td>
<td>38</td>
<td>43</td>
<td>4.12</td>
<td>1.27</td>
<td>1.26</td>
<td>1.59</td>
<td>2.55</td>
<td></td>
</tr>
<tr>
<td>DS41</td>
<td>Present</td>
<td>3.47</td>
<td>2.06</td>
<td>41</td>
<td>46</td>
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<td>1.81</td>
<td>3.34</td>
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<tr>
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<td>1.90</td>
<td>41</td>
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<td>3.59</td>
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<td>1.35</td>
<td>1.82</td>
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</tr>
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<td>1.24</td>
<td>1.62</td>
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<td>1.00</td>
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<td>0.96</td>
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<td>37</td>
<td>4.48</td>
<td>1.13</td>
<td>1.09</td>
<td>1.46</td>
<td>1.80</td>
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<tr>
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<td>High</td>
<td>3.04</td>
<td>1.15</td>
<td>35</td>
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<td>4.30</td>
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<td>1.15</td>
<td>1.52</td>
<td>2.04</td>
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<td>0.97</td>
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<td>44</td>
<td>3.62</td>
<td>1.30</td>
<td>1.29</td>
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<td>3.04</td>
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<tr>
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<td>40</td>
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<td>3.42</td>
<td>1.33</td>
<td>1.29</td>
<td>1.91</td>
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<tr>
<td>DW41</td>
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<td>2.66</td>
<td>1.09</td>
<td>39</td>
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<td>3.42</td>
<td>1.30</td>
<td>1.26</td>
<td>1.92</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>GR5</td>
<td>Present</td>
<td>6.65</td>
<td>8.20</td>
<td>43</td>
<td>51</td>
<td>6.55</td>
<td>1.43</td>
<td>1.50</td>
<td>1.00</td>
<td>2.15</td>
<td></td>
</tr>
</tbody>
</table>

$\pi$: Accident to conflict conversion factor  
$\text{CoV}$: Coefficient of variation  
$\dot{\lambda}$: Accident predictions  
P(X): The probability of observing the actual number of accidents based on the predictions

According to Table 7.21 the high definition of RRU is linked to the indices that produced the lowest overall ratio to the best. Severity index SC, which considers re-scaling the conflicts according to their severity grade and their category, was found to produce the lowest overall ratio to the best. Although severity index SC reported the smallest coefficient of variation of $\pi$ and the average coefficient of variation of the predictions, it did not produce the highest probability of observing the actual number of accidents. On other hand, the present definition of serious conflicts GR5 produced the highest probability of observing the actual number of accidents but not the smallest coefficients of variation, which were actually the highest among other indices.
Conflict Sub-group approach

The results of investigating various definition under conflict sub-group approach as a means of applying the Swedish TCT in Jordan as accident predictive tool versus the present definition of serious conflicts GR5 are presented in Table 7.22.

Table 7.22 The validity of conflict definitions based on various conflict sub-groups and relevant road-user definitions for signalised junctions in Jordan.

<table>
<thead>
<tr>
<th>Conflict sub-group</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean $\pi_{10^6}$</th>
<th>Variance VAR [$\pi$] $10^{-12}$</th>
<th>CoV ($\pi$) %</th>
<th>CoV ($\hat{\lambda}$) %</th>
<th>P(x) $10^4$</th>
<th>$\frac{CoV(\pi)}{CoV(\pi_{min})}$ A</th>
<th>$\frac{CoV(\hat{\lambda})}{CoV(\hat{\lambda}_{min})}$ B</th>
<th>$\frac{1}{P(Xi)}$</th>
<th>Overall ratio to the best A x b x c</th>
<th>P(Xmax) C</th>
</tr>
</thead>
<tbody>
<tr>
<td>V $\geq$ 20</td>
<td>Present</td>
<td>All</td>
<td>85.10</td>
<td>1080.00</td>
<td>39</td>
<td>82</td>
<td>43.50</td>
<td>5.57</td>
<td>3.73</td>
<td>1.00</td>
<td>20.77</td>
<td></td>
</tr>
<tr>
<td>V $\leq$ 20</td>
<td>Present</td>
<td>All</td>
<td>18.10</td>
<td>18.30</td>
<td>24</td>
<td>42</td>
<td>4.63</td>
<td>3.43</td>
<td>1.91</td>
<td>9.40</td>
<td>61.50</td>
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</tr>
<tr>
<td>TA $\leq$ 0.75</td>
<td>Present</td>
<td>All</td>
<td>7.65</td>
<td>9.03</td>
<td>39</td>
<td>47</td>
<td>6.54</td>
<td>5.57</td>
<td>2.14</td>
<td>6.65</td>
<td>79.17</td>
<td></td>
</tr>
<tr>
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<td>All</td>
<td>6.89</td>
<td>12.80</td>
<td>52</td>
<td>69</td>
<td>2.24</td>
<td>7.43</td>
<td>3.14</td>
<td>19.42</td>
<td>452.45</td>
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</tr>
<tr>
<td>TSS11</td>
<td>Present</td>
<td>All</td>
<td>12.20</td>
<td>14.40</td>
<td>31</td>
<td>47</td>
<td>14.70</td>
<td>4.43</td>
<td>2.14</td>
<td>2.96</td>
<td>28.00</td>
<td></td>
</tr>
<tr>
<td>V $\geq$ 20</td>
<td>Serious</td>
<td>All</td>
<td>110.00</td>
<td>1270.00</td>
<td>32</td>
<td>77</td>
<td>41.40</td>
<td>4.57</td>
<td>3.50</td>
<td>1.05</td>
<td>16.81</td>
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<tr>
<td>V $\geq$ 20</td>
<td>Serious</td>
<td>All</td>
<td>25.20</td>
<td>11.60</td>
<td>14</td>
<td>41</td>
<td>6.91</td>
<td>2.00</td>
<td>1.86</td>
<td>6.30</td>
<td>23.46</td>
<td></td>
</tr>
<tr>
<td>TA $\leq$ 0.75</td>
<td>Serious</td>
<td>All</td>
<td>8.31</td>
<td>1.35</td>
<td>14</td>
<td>28</td>
<td>5.86</td>
<td>2.00</td>
<td>1.27</td>
<td>7.42</td>
<td>18.90</td>
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<tr>
<td>TSN124</td>
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<td>All</td>
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<td>82</td>
<td>99</td>
<td>3.20</td>
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<td>4.50</td>
<td>13.59</td>
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<tr>
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<td>Serious</td>
<td>All</td>
<td>18.30</td>
<td>50.10</td>
<td>39</td>
<td>48</td>
<td>5.56</td>
<td>5.57</td>
<td>2.18</td>
<td>7.82</td>
<td>95.10</td>
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</tr>
<tr>
<td>V $\geq$ 20</td>
<td>High</td>
<td>All</td>
<td>40.70</td>
<td>245.00</td>
<td>38</td>
<td>53</td>
<td>11.80</td>
<td>5.43</td>
<td>2.41</td>
<td>3.69</td>
<td>48.21</td>
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<tr>
<td>V $\geq$ 20</td>
<td>High</td>
<td>All</td>
<td>9.23</td>
<td>4.24</td>
<td>22</td>
<td>31</td>
<td>4.74</td>
<td>3.14</td>
<td>1.41</td>
<td>9.18</td>
<td>40.64</td>
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</tr>
<tr>
<td>TA $\leq$ 0.75</td>
<td>High</td>
<td>All</td>
<td>5.19</td>
<td>3.32</td>
<td>35</td>
<td>41</td>
<td>4.84</td>
<td>5.00</td>
<td>1.86</td>
<td>8.99</td>
<td>83.75</td>
<td></td>
</tr>
<tr>
<td>TSN124</td>
<td>High</td>
<td>All</td>
<td>9.36</td>
<td>11.00</td>
<td>35</td>
<td>44</td>
<td>1.66</td>
<td>5.00</td>
<td>2.00</td>
<td>26.20</td>
<td>262.05</td>
<td></td>
</tr>
<tr>
<td>TSS11</td>
<td>High</td>
<td>All</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td></td>
</tr>
<tr>
<td>V $\geq$ 20</td>
<td>High</td>
<td>Serious</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td></td>
</tr>
<tr>
<td>V $\geq$ 20</td>
<td>Serious</td>
<td>All</td>
<td>12.00</td>
<td>11.10</td>
<td>28</td>
<td>44</td>
<td>5.84</td>
<td>4.00</td>
<td>2.00</td>
<td>7.45</td>
<td>59.59</td>
<td></td>
</tr>
<tr>
<td>TA $\leq$ 0.75</td>
<td>High</td>
<td>Serious</td>
<td>8.56</td>
<td>3.07</td>
<td>32</td>
<td>40</td>
<td>8.28</td>
<td>4.57</td>
<td>1.82</td>
<td>5.25</td>
<td>43.67</td>
<td></td>
</tr>
<tr>
<td>TSN124</td>
<td>High</td>
<td>Serious</td>
<td>20.60</td>
<td>271.00</td>
<td>80</td>
<td>116</td>
<td>6.74</td>
<td>11.43</td>
<td>5.27</td>
<td>6.45</td>
<td>388.02</td>
<td></td>
</tr>
<tr>
<td>TSS11</td>
<td>High</td>
<td>Serious</td>
<td>14.40</td>
<td>0.98</td>
<td>7</td>
<td>22</td>
<td>4.82</td>
<td>1.00</td>
<td>1.00</td>
<td>9.02</td>
<td>9.02</td>
<td></td>
</tr>
</tbody>
</table>

$\pi$: Accident to conflict conversion factor  
CoV: Coefficient of variation  
$\hat{\lambda}$: Accident predictions  
P(Xi): The probability of observing the actual number of accidents based on the predictions  
1): Maximum likelihood function did not converge.
The results in Table 7.22 do not give any preference for any of the RRU definitions. Some conflict sub-groups that were based on the high definition of RRU produced a low overall ratio to the best and some other sub-groups based on the present definition of RRU also produced a low overall ratio to the best. However, the lowest overall ratio to the best was reported for the conflict sub-group TSS113, which includes serious conflicts that were defined based on the high definition of RRU; the present definition of serious conflict, GR5, was used to define serious conflicts. TSS113 includes all serious conflicts involving a road-user that is subjected to interact with at least one and not more than three road-users measured one second before the conflict.

Table 7.22 indicates that conflict sub-groups that were defined on the present definition of RRU were found to produce the highest probability of observing the actual number of accidents. Specifically, conflict sub-groups that were formed by considering the speed of the RRU as a selection criterion. For instance conflict sub-group $V \geq 30$ produced the highest probability of observing the actual number of accidents. Similar results were reported if the sub-groups were for all conflicts or only serious conflicts.

Finally, there is a clear trend that the inclusion of serious conflicts instead of all conflicts produced lower overall ratio to the best, particularly if the present definition of RRU is used as a basis for defining the conflict characteristics.
Overall conclusion of verifying Hypothesis 1: three-approach comparison.

The overall comparison between different approaches was based on the definitions that were relatively found to be the most valid definitions for accident prediction at signalised junctions; the results reported in Table 7.23.

**Table 7.23** The validity of conflict definitions for signalised junctions in Jordan based on the most valid definitions when considering each approach of analysis.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean $\pi$</th>
<th>Variance $\text{VAR}(\pi)$</th>
<th>$\text{CoV}(\pi)$</th>
<th>$\text{CoV}(\lambda)$</th>
<th>$\text{P}(\pi)$</th>
<th>$\text{P}(\lambda)$</th>
<th>$\text{P}(X \text{ max})$</th>
<th>$\text{P}(X \text{ min})$</th>
<th>$\frac{1}{\text{P}(X \text{ max})}$</th>
<th>Overall ratio to the best $A \times b \times c$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold</strong></td>
<td>GR5</td>
<td>Present</td>
<td>6.65</td>
<td>8.20</td>
<td>43</td>
<td>51</td>
<td>6.55</td>
<td>6.14</td>
<td>2.32</td>
<td>6.64</td>
<td>94.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GR3</td>
<td>High</td>
<td>4.19</td>
<td>1.11</td>
<td>25</td>
<td>30</td>
<td>3.64</td>
<td>3.57</td>
<td>1.36</td>
<td>11.95</td>
<td>58.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GR4</td>
<td>High</td>
<td>4.24</td>
<td>1.17</td>
<td>26</td>
<td>31</td>
<td>3.85</td>
<td>3.71</td>
<td>1.41</td>
<td>11.30</td>
<td>59.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>High</td>
<td>4.58</td>
<td>1.92</td>
<td>30</td>
<td>36</td>
<td>4.22</td>
<td>4.29</td>
<td>1.64</td>
<td>10.31</td>
<td>72.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Severity Index</strong></td>
<td>SC</td>
<td>Present</td>
<td>3.43</td>
<td>1.30</td>
<td>33</td>
<td>38</td>
<td>4.73</td>
<td>4.71</td>
<td>1.73</td>
<td>9.20</td>
<td>74.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>High</td>
<td>2.80</td>
<td>0.72</td>
<td>30</td>
<td>34</td>
<td>4.33</td>
<td>4.29</td>
<td>1.55</td>
<td>10.05</td>
<td>66.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-Group</strong></td>
<td>V≥30</td>
<td>Present</td>
<td>All</td>
<td>85.10</td>
<td>1080.0</td>
<td>39</td>
<td>82</td>
<td>43.50</td>
<td>5.57</td>
<td>3.73</td>
<td>1.00</td>
<td>20.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V≥30</td>
<td>Present</td>
<td>Serious</td>
<td>110.00</td>
<td>1270.0</td>
<td>32</td>
<td>77</td>
<td>41.40</td>
<td>4.57</td>
<td>3.50</td>
<td>1.05</td>
<td>16.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TSS113</td>
<td>High</td>
<td>Serious</td>
<td>14.40</td>
<td>0.98</td>
<td>7</td>
<td>22</td>
<td>4.82</td>
<td>1.00</td>
<td>1.00</td>
<td>9.02</td>
<td>9.02</td>
<td></td>
</tr>
</tbody>
</table>

π: Accident to conflict conversion factor

CoV: Average coefficient of variation

λ: Accident predictions

P(X): The probability of observing the actual number of accidents based on the predictions

Table 7.23 indicates the following:

First, the lowest overall ratio was reported for conflict sub-group TSS113 that includes all serious conflicts; it produced the lowest coefficient of variation of both $\pi$ and the average of the predictions $\lambda$, but it produced a low probability of observing the actual number of accidents.

Second, although conflict sub-group V≥30 based on the present definition of RRU produced the highest probability of observing the actual number of accidents, it did not produce the lowest overall ratio to the best.

Third, there is considerable difference between the performance of the different conflict definitions that were included under the three investigated approaches. The threshold approach, including the present definition of serious conflicts, did not produce the best accident predictions. The inclusion of severity index approach did not provide better accident predictions either. Conflict sub-group approach provides the best accident
predictions. Definitions under this approach produced the lowest overall ratio to the best, including its three components.

Comparison between valid definitions in the two countries

Verification of Sub-Hypothesis (2-A)

Comparing conflict definitions that were valid for accident predictions in each country indicated that conversion factors developed in Jordan were lower in their values and variances than in Sweden. However, Mann-Whitney test results indicated that there are no significant differences between conversion factors developed in each country, Table 7.24.

**Table 7.24** Accident to conflict conversion factors “πs” Conversion factors based on conflict definitions that were proven to be valid for accident prediction purposes for signalised junctions in each country.

<table>
<thead>
<tr>
<th>Conflic definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Country where it has high validity</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>(10^-6)</td>
<td>(10^-12)</td>
<td>Overall ratio to the best</td>
</tr>
<tr>
<td></td>
<td>GR3</td>
<td>High</td>
<td>Jordan</td>
<td>21.00</td>
<td>74.90</td>
<td>33.66</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>High</td>
<td>Jordan</td>
<td>10.70</td>
<td>32.10</td>
<td>9.67</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>High</td>
<td>Sweden</td>
<td>13.50</td>
<td>40.30</td>
<td>8.64</td>
</tr>
<tr>
<td>Severity Index</td>
<td>SC</td>
<td>High</td>
<td>Sweden</td>
<td>6.25</td>
<td>13.70</td>
<td>74.38</td>
</tr>
<tr>
<td></td>
<td>N321</td>
<td>High</td>
<td>Jordan</td>
<td>6.69</td>
<td>13.40</td>
<td>48.82</td>
</tr>
<tr>
<td>Sub-group</td>
<td>V ≥ 30</td>
<td>Present</td>
<td>All</td>
<td>166.00</td>
<td>6030.00</td>
<td>42.04</td>
</tr>
<tr>
<td></td>
<td>V ≥ 30</td>
<td>Present</td>
<td>Serious</td>
<td>240.00</td>
<td>18300.00</td>
<td>82.93</td>
</tr>
<tr>
<td></td>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>All</td>
<td>15.60</td>
<td>63.00</td>
<td>17.78</td>
</tr>
<tr>
<td></td>
<td>V ≥ 30</td>
<td>High</td>
<td>Serious</td>
<td>137.00</td>
<td>9770.00</td>
<td>22.02</td>
</tr>
<tr>
<td></td>
<td>TS113</td>
<td>High</td>
<td>Serious</td>
<td>28.60</td>
<td>592.00</td>
<td>119.40</td>
</tr>
</tbody>
</table>

1) The validity is based on the results of this study.
2) Overall ratio to the best is the calculated ratio for the proposed definition in relation to all other definition proposed in each country.
3) Maximum likelihood did not converge.

Table 7.24 indicates that the definitions that were valid in Sweden were different in Jordan. The most valid definitions Sweden were not in Jordan and vice versa. It is possible to conclude that the reported results for signalised junction verified the Sub-hypothesis (2-A). Similar results were reported for non-signalised junctions.
Prediction differences due to country

Verifying of Sub-Hypothesis (2-B)

The verification of Sub-Hypothesis (2-B) was also completed by comparing the predictions made for signalised junctions in Jordan based on conversion factors that were proven to be the most valid tools for accident predictions in each country (Table 7.25). The reported overall ratios to the best in Table 7.25 are not equal to those presented in Table 7.24, which are corresponding to the predictions made for signalised junctions in each country. Nevertheless, they provided similar results as the lowest overall ratio to the best based on conversion factors developed in Sweden is different from that in Jordan.

Predictions based on the conversion factors developed in Sweden provided higher coefficients of variations than in Jordan. Further, they produced lower probability of observing the actual number of accidents compared to Jordan. Therefore, the reported results verified the tested Sub-hypothesis (2-A) implying that predictions based on conversion factors developed in Sweden were not as good as those in Jordan.

Table 7.25  
Comparison between accident predictions made for signalised junctions in Jordan based on conversion factors developed in each country for the most valid definitions of conflicts.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Predictions based on factors developed for signalised junctions in Sweden</th>
<th>Predictions based on factors developed for signalised junction in Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CoV ((\pi)) %</td>
<td>CoV ((\lambda)) %</td>
</tr>
<tr>
<td>Threshold</td>
<td></td>
<td></td>
<td></td>
<td>41</td>
<td>46</td>
</tr>
<tr>
<td>Gr5</td>
<td>Present</td>
<td></td>
<td></td>
<td>68</td>
<td>74</td>
</tr>
<tr>
<td>Gr3</td>
<td>High</td>
<td></td>
<td></td>
<td>53</td>
<td>57</td>
</tr>
<tr>
<td>Gr5</td>
<td>High</td>
<td></td>
<td></td>
<td>47</td>
<td>51</td>
</tr>
<tr>
<td>Sub-grouping</td>
<td></td>
<td></td>
<td></td>
<td>V(\geq 30)</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>V(\geq 30)</td>
<td>Present</td>
<td>Serious</td>
<td>56</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>TA (\leq 0.75)</td>
<td>High</td>
<td>All</td>
<td>51</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>V(\geq 30)</td>
<td>High</td>
<td>Serious</td>
<td>81</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>TSS113</td>
<td>High</td>
<td>Serious</td>
<td>85</td>
<td>95</td>
</tr>
</tbody>
</table>

\(\pi\): Accident to conflict conversion factor  
CoV: Coefficient of variation  
CoV: Average coefficient of variation  
\(\lambda\): Accident predictions  
P(x): The probability of observing the actual number of accidents based on the predictions  
1) Maximum likelihood did not converge
7.2.3 Both junction types together

Conversion factors developed for non-signalised junctions in Jordan were lower in their values than those developed for signalised junctions (Table 7.26). The variances of conversion factors developed for non-signalised junctions were also lower with few exceptions for definitions developed under conflict sub-group approach. Nevertheless, (M-W) test indicated that there are no significant differences between conversion factors due to traffic control type.

Table 7.26 Mann-Whitney test results aimed at investigating the existence of any differences between accident to conflict conversion factors (π) developed for non-signalised and signalised junctions in Jordan.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition 1)</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean $\pi \times 10^{-6}$</th>
<th>Variance $\text{VAR}[\pi] \times 10^{-12}$</th>
<th>Mean $\pi \times 10^{-6}$</th>
<th>Variance $\text{VAR}[\pi] \times 10^{-12}$</th>
<th>M-W test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR5</td>
<td>Present</td>
<td></td>
<td></td>
<td>4.02</td>
<td>8.03</td>
<td>6.65</td>
<td>8.20</td>
<td>0.23</td>
</tr>
<tr>
<td>GR6</td>
<td>Present</td>
<td></td>
<td></td>
<td>6.52</td>
<td>35.10</td>
<td>11.50</td>
<td>41.20</td>
<td>0.38</td>
</tr>
<tr>
<td>GR3</td>
<td>High</td>
<td></td>
<td></td>
<td>1.69</td>
<td>0.42</td>
<td>4.19</td>
<td>1.11</td>
<td>0.27</td>
</tr>
<tr>
<td>G5</td>
<td>High</td>
<td></td>
<td></td>
<td>1.80</td>
<td>0.81</td>
<td>4.58</td>
<td>1.92</td>
<td>0.32</td>
</tr>
<tr>
<td>Severity Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>High</td>
<td></td>
<td></td>
<td>1.56</td>
<td>0.27</td>
<td>3.53</td>
<td>1.71</td>
<td>0.33</td>
</tr>
<tr>
<td>SC</td>
<td>High</td>
<td></td>
<td></td>
<td>1.13</td>
<td>0.34</td>
<td>2.80</td>
<td>0.72</td>
<td>0.28</td>
</tr>
<tr>
<td>Sub Grouping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V≥30</td>
<td>Present</td>
<td>All</td>
<td></td>
<td>-</td>
<td>-</td>
<td>85.10</td>
<td>1080.00</td>
<td></td>
</tr>
<tr>
<td>V≥30</td>
<td>Present</td>
<td>Serious</td>
<td></td>
<td>-</td>
<td>-</td>
<td>110.00</td>
<td>1270.00</td>
<td></td>
</tr>
<tr>
<td>V≥20</td>
<td>Present</td>
<td>Serious</td>
<td></td>
<td>11.20</td>
<td>86.00</td>
<td>25.20</td>
<td>11.60</td>
<td>0.28</td>
</tr>
<tr>
<td>V≥20</td>
<td>High</td>
<td>Serious</td>
<td></td>
<td>4.36</td>
<td>0.70</td>
<td>12.00</td>
<td>11.10</td>
<td>0.33</td>
</tr>
<tr>
<td>TS5113</td>
<td>High</td>
<td>Serious</td>
<td></td>
<td>4.47</td>
<td>10.40</td>
<td>14.40</td>
<td>0.98</td>
<td>0.33</td>
</tr>
</tbody>
</table>

1) Conversion factors for the most valid definitions of conflicts at each type of junction were used in the above analysis
2) Maximum likelihood function did not converge.

No significant differences in results suggest that common conversion factors could be developed for non-signalised and signalised junctions in Jordan. Conversion factors were developed for both junction types together rather than for each type separately. Definitions that were valid for accident predictions at each type of junction in Jordan were used to develop the most valid definition for both junction types together. Conflict definitions that were the most valid for each type of junction in Sweden were also investigated (Table 7.27).
Table 7.27  The validity of conflict definitions for both junction types together based on the most valid definitions for each type of junction in Jordan.

<table>
<thead>
<tr>
<th>Conflict definition</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Mean ( \pi )</th>
<th>Variance ( \text{VAR} [\pi] )</th>
<th>CoV (( \pi )) %</th>
<th>CoV (( \hat{\lambda} )) %</th>
<th>( P(\pi) )</th>
<th>( \frac{\text{CoV}(\pi)}{\text{CoV}(\hat{\lambda})} )</th>
<th>( \frac{\text{CoV}(\pi)}{\text{CoV}(\hat{\lambda}, \min)} )</th>
<th>( \frac{1}{\text{POX}} )</th>
<th>Crash ratio to the best average percentage</th>
<th>Overall ratio to the best average percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR5</td>
<td>Present</td>
<td>5.64</td>
<td>10.10</td>
<td>56</td>
<td>65</td>
<td>0.088</td>
<td>1.44</td>
<td>1.33</td>
<td>14.16</td>
<td>26.96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR6</td>
<td>Present</td>
<td>10.10</td>
<td>48.10</td>
<td>69</td>
<td>80</td>
<td>0.22</td>
<td>1.77</td>
<td>1.63</td>
<td>5.54</td>
<td>15.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR3</td>
<td>High</td>
<td>3.27</td>
<td>2.01</td>
<td>43</td>
<td>50</td>
<td>0.04</td>
<td>1.10</td>
<td>1.02</td>
<td>30.39</td>
<td>34.19</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>GR4</td>
<td>High</td>
<td>3.30</td>
<td>2.15</td>
<td>44</td>
<td>51</td>
<td>0.043</td>
<td>1.13</td>
<td>1.04</td>
<td>28.97</td>
<td>34.02</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>G5</td>
<td>High</td>
<td>3.53</td>
<td>3.17</td>
<td>50</td>
<td>56</td>
<td>0.05</td>
<td>1.28</td>
<td>1.14</td>
<td>24.90</td>
<td>36.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR6</td>
<td>High</td>
<td>4.40</td>
<td>3.96</td>
<td>45</td>
<td>53</td>
<td>0.06</td>
<td>1.15</td>
<td>1.08</td>
<td>21.60</td>
<td>26.96</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Severity Index</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Present</td>
<td>2.90</td>
<td>1.50</td>
<td>43</td>
<td>49</td>
<td>0.06</td>
<td>1.10</td>
<td>1.00</td>
<td>21.05</td>
<td>23.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>High</td>
<td>2.30</td>
<td>9.20</td>
<td>133</td>
<td>51</td>
<td>0.05</td>
<td>3.41</td>
<td>1.04</td>
<td>27.43</td>
<td>97.37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>High</td>
<td>3.00</td>
<td>1.80</td>
<td>45</td>
<td>143</td>
<td>0.06</td>
<td>1.15</td>
<td>2.92</td>
<td>21.95</td>
<td>73.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N321</td>
<td>High</td>
<td>1.91</td>
<td>1.14</td>
<td>56</td>
<td>62</td>
<td>0.03</td>
<td>1.44</td>
<td>1.27</td>
<td>37.58</td>
<td>68.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ds41</td>
<td>Low</td>
<td>3.04</td>
<td>2.62</td>
<td>53</td>
<td>60</td>
<td>0.0004</td>
<td>1.36</td>
<td>1.22</td>
<td>2824</td>
<td>4700</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub Groups</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V≥30</td>
<td>Present</td>
<td>85.50</td>
<td>1610.0</td>
<td>47</td>
<td>91</td>
<td>1.24</td>
<td>1.21</td>
<td>1.86</td>
<td>1.00</td>
<td>2.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>4.34</td>
<td>3.93</td>
<td>46</td>
<td>53</td>
<td>0.06</td>
<td>1.18</td>
<td>1.08</td>
<td>20.50</td>
<td>26.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V≥20</td>
<td>High</td>
<td>9.50</td>
<td>13.90</td>
<td>39</td>
<td>54</td>
<td>0.10</td>
<td>1.00</td>
<td>1.10</td>
<td>11.92</td>
<td>13.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS113</td>
<td>High</td>
<td>10.80</td>
<td>18.90</td>
<td>40</td>
<td>50</td>
<td>0.16</td>
<td>1.03</td>
<td>1.02</td>
<td>7.85</td>
<td>8.21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( \pi \): Accident to conflict conversion factor  
CoV: Coefficient of variation  
\( \hat{\lambda} \): Accident predictions  
POX: The probability of observing the actual number of accidents based on the predictions

According to Table 7.27, serious conflict sub-group V≥30, based on the present definition of RRU and threshold GR5, reported the lowest overall ratio to the best. It produced the highest probability of observing the actual number of accidents and it was among the definitions that have a low coefficient of variation of \( \pi \). This conflict sub-group recorded the highest probability of observing the actual number of accidents at signalised junctions, but it did not produce the lowest overall ratio to the best for signalised junctions. It was not the most valid definition of conflict at non-signalised junctions.

Threshold GR6 (based on the present definition of RRU) produced the second highest probability of observing the actual number of accidents and it was among the definitions that produced a low overall ratio to the best. This threshold did not produce the lowest overall ratio to the best among other threshold definitions for each type of junction. However, it should be pointed out that the differences in the overall ratio to the best for the proposed threshold were small.

The results presented in Table 7.27 do not give any preference to the present or the high definition of RRU. Conflict sub-group V≥30 (based on the present definition of RRU)
produced the lowest overall ratio to the best, was. Conflict sub-group TSS113 (based on the high definition of RRU) produced the second lowest overall ratio to the best.

The results in Table 7.27 indicated that the definitions proposed under conflict sub-group approach produced the lowest overall ratio to the best. In contrast, definitions under the conflict severity index approach produced poor results compared to the definitions that produced the lowest overall ratio to the best.

Predictions based on both junction types conversion factors

Accident predictions using conversion factors developed for both junction types together were compared to those based on conversion factors developed for each type of junction (i.e. non-signalled and signalled junctions). The predictions were limited to the most valid definitions reported for both junction types together.

The results reported in Table 7.28 show different trends depend on the junction type. The predictions made for non-signalled junctions, using conversion factors developed for both junction types together produced better predictions than those reported when conversion factors developed for non-signalled junctions alone. They produced lower coefficients of variation for the predictions and a higher probability of observing the actual number of accidents.

Table 7.28 Comparison between accident predictions based on conversion factors developed for each individual type of junction in Jordan with predictions based on conversion factors developed for both junction types together.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Non-signalled junctions</th>
<th>Signalised junctions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Predictions made based on conversion factors for both junction types together</td>
<td>Predictions made based on conversion factors for non-signalled junctions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CoV ((\bar{\lambda})) (%)</td>
<td>(\bar{\lambda})</td>
</tr>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td></td>
<td>56</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td></td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>High</td>
<td></td>
<td>45</td>
<td>54</td>
</tr>
<tr>
<td>Sub groupings</td>
<td>V≥30</td>
<td>Present, Serious</td>
<td></td>
<td>47</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>V≥20</td>
<td>High, Serious</td>
<td></td>
<td>39</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>TSS113</td>
<td>High</td>
<td></td>
<td>40</td>
<td>51</td>
</tr>
</tbody>
</table>

\(n\): Accident to conflict conversion factor  
CoV: Coefficient of variation  
\(\bar{\lambda}\): Accident predictions  
P(\(X\)): The probability of observing the actual number of accidents based on the predictions  
The maximum likelihood function did not converge.
Predictions made for signalised junctions using conversion factors developed for both junction types together produced higher prediction coefficients of variation compared to the predictions based on conversion factors developed for this type of junction. The probability of observing the actual number of accidents was slightly higher for predictions based on conversion factors developed for both junction types together.

To sum up, common conversion factors for all types of junctions provided better accident predictions for non-signalised junctions compared to signalised junctions.

Comparison between valid definitions in the two countries

Verification of Sub-Hypothesis (2-A)

Comparing the definitions of conflicts that were valid for accident predictions in each country indicated that conversion factors developed in Jordan were lower in their values and variances than in Sweden, Table 7.29. However, Mann-Whitney test results indicated that there are no significant differences between conversion factors developed in each country.

**Table 7.29** Accident to conflict conversion factors “πs” for conflict definitions that were proven to be valid for accident prediction purposes for both junction types together in each country.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Country where it has high validity</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean $\pi_{10}^{0.6}$</td>
<td>Variance $\text{VAR}(\pi_{10}^{0.6})$</td>
<td>Overall ratio to the best</td>
</tr>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td>Jordan</td>
<td>17.10</td>
<td>215.00</td>
<td>4.71</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td>Sweden &amp; Jordan</td>
<td>38.30</td>
<td>862.00</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>Gr5</td>
<td>High</td>
<td>Sweden</td>
<td>9.11</td>
<td>74.90</td>
<td>2.03</td>
</tr>
<tr>
<td></td>
<td>Gr6</td>
<td>High</td>
<td>Jordan</td>
<td>11.60</td>
<td>118.00</td>
<td>2.15</td>
</tr>
<tr>
<td>Severity index</td>
<td>N321</td>
<td>High</td>
<td>Sweden</td>
<td>5.32</td>
<td>24.50</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>V≥30</td>
<td>Present</td>
<td>Serious</td>
<td>616.00</td>
<td>507000</td>
<td>7.1E+05</td>
</tr>
<tr>
<td></td>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>All</td>
<td>14.20</td>
<td>207.00</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td>V≥20</td>
<td>High</td>
<td>Serious</td>
<td>27.70</td>
<td>523.00</td>
<td>3.82</td>
</tr>
<tr>
<td></td>
<td>TSS113</td>
<td>High</td>
<td>Serious</td>
<td>82.20</td>
<td>4830.00</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Overall ratio to the best is estimated for the proposed definition in relation to all other investigated definitions in each country.

Table 7.29 indicates that not all the definitions that were among the most valid ones in Sweden were the most valid in Jordan. Some of the definitions were valid in both countries, such as threshold GR6 (based on the present definition of RRU). It is possible to conclude that the reported results for both junction types together did not provide a clear-cut evidence to verify the Sub-hypothesis (2-A). It was the same finding reported at non-signalised junctions.
Prediction difference due to country

Verifying of Sub-Hypothesis (2-B)

The verification of Sub-hypothesis (2-B) was also completed by comparing the predictions made for junctions in Jordan based on conversion factors that were proven to be the most valid tool in each country. The validity of accident predictions for signalised junctions in Jordan based on the most valid definitions of conflicts in each country are presented in Table 7.30. The overall ratios to the best (Table 7.30) are not equal to those presented in Table 7.29, which were corresponding to the predictions made for both junction types together in each country. They provided similar results since the lowest overall ratio in Sweden was different from Jordan.

**Table 7.30** Comparison between accident predictions obtained in Jordan for both junction types together based on conversion factors developed for each country for the most valid definitions of conflicts.

<table>
<thead>
<tr>
<th>Conflict definition approach</th>
<th>Conflict definition</th>
<th>Relevant road-user definition</th>
<th>Severity group</th>
<th>Predictions made based on factors developed for both junction types together in Sweden</th>
<th>Predictions made based on factors developed for both junction types together in Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CoV (π) %</td>
<td>CoV (λ) %</td>
</tr>
<tr>
<td>Threshold</td>
<td>GR5</td>
<td>Present</td>
<td>86</td>
<td>96</td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td>77</td>
<td>89</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>High</td>
<td>95</td>
<td>104</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>High</td>
<td>94</td>
<td>103</td>
<td>0.035</td>
</tr>
<tr>
<td>Severity Index</td>
<td>N321</td>
<td>High</td>
<td>93</td>
<td>101</td>
<td>0.02</td>
</tr>
<tr>
<td>Sub-Grouping</td>
<td>TA ≤ 0.75</td>
<td>High</td>
<td>102</td>
<td>115</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>V220</td>
<td>High</td>
<td>83</td>
<td>97</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>TSS113</td>
<td>High</td>
<td>106</td>
<td>118</td>
<td>0.03</td>
</tr>
</tbody>
</table>

\( a \): Accident to conflict conversion factor  
CoV: Coefficient of variation  
\( \lambda \): Accident predictions  
\( P(x) \): The probability of observing the actual number of accidents based on the predictions

The predictions made by using conversion factors developed in Sweden provide higher coefficients of variation of the predictions than in Jordan. They produced a lower probability of observing the actual number of accidents compared to those reported for conversion factors developed in Jordan. Therefore, it is possible to conclude that predictions based on conversion factors developed in Sweden (when considering both junction types together) were not as good as in Jordan. This verified the tested sub-hypothesis.
Conclusions

- The most valid conflict definitions in Sweden are not the most valid definitions of conflicts in Jordan, particularly for signalised junctions. Some conflict definitions, however, have high validity for non-signalised junctions in both countries if based on conflict sub-group approach.

- The most valid conflict definitions developed for each junction type were those based on the high definition of RRU. It is the present definition of RRU that was linked to the most valid conflict definitions developed for both junction types together.

- Definitions that were based on the high definition of RRU produced small coefficients of variation while definitions that were based on the present definition of RRU produced high probability of observing the actual number of accidents.

- Defining conflicts by the alternative thresholds alone did not produce the most valid definition of conflicts. This was evident from the results reported at each type of junction as well as for both junction types together.

- Definitions under the conflict sub-group approach were the most valid for conflicts in Jordan. The most valid definitions for each type of junctions and for both junction types together were as follows:
  - Conflict sub-group $V \geq 20$ for non-signalised junctions: It includes all serious conflicts categorised by the present threshold GR5 and high definition of RRU that involve a road-user travelling at a speed of $\geq 20$ km/h.
  - Conflict sub-group TSS113 for signalised junctions: It includes all serious conflicts categorised by the present threshold GR5 and high definition of RRU that involve a road-user interacting with at least one and not more than three other road-users measured one second before the conflict.
  - Conflict sub-group $V \geq 30$ for both junction types: It includes all serious conflicts categorised by the present threshold GR5 and high definition of RRU that involve a driver using at least a speed of $\geq 30$ km/h.

- Conversion factors developed in Sweden are higher in value than those in Jordan, even though statistical tests failed to report significant differences.

- Conversion factors developed at non-signalised junctions in Jordan were lower in value than those reported at signalised junctions. This was not the case in Sweden as the difference was marginal.

- Investigating the validity of using conversion factors developed in Sweden that correspond to the most valid definition of conflicts in Jordan for accident predictions indicates the following:
Accident predictions completed for signalised junctions in Jordan based on conversion factors developed in Sweden were not as good as the predictions based on conversion factors developed in Jordan. The same was applicable if the predictions were based on conversion factors that were developed for both junction types together.

Results from non-signalised junctions were different according to the conflict definition analysis approach. The predictions were very poor when the threshold approach was considered. The definition under the conflict sub-groups produced a high probability of observing the actual number of accidents, but with a higher variation, if compared to predictions based on conversion factors developed in Jordan.

Shifting the threshold to the left of TA-speed graph, i.e. to the more severe direction, seems to improve the prediction concerning the probability of observing the actual number of accident. This shift was often associated with an increase in the variance of accidents to conflict ratios $\pi$'s as well of the predictions. This conclusion is applicable for Sweden and Jordan.
7.2.4 Comparison of accidents and conflicts in the two countries

The results indicated that there are differences between predictions based on conversion factors developed in each country. The differences in conversion factors resulted in different predictions despite M-W test results did not indicate the existence of any statistical differences.

For example, conversion factors for non-signalised junctions in Sweden based on present definition of RRU were at least five times the value in Jordan (Figure 7.2). Thus, a conflict recorded in Sweden has a probability of producing an accident at least five times as much as a conflict recorded in Jordan. This implies that every 50,000 conflicts recorded at non-signalised junctions in Sweden are expected to produce one accident while the corresponding figure in Jordan would be around every 250,000 conflicts.

![Conversion factor means and variances of the present threshold GR5 based on the present RRU definition. All values should be multiplied by 10^6.](image)

**Figure 7.2** Conversion factor means and variances of the present threshold GR5 based on the present RRU definition. All values should be multiplied by $10^6$.

The coefficient of variation of $\pi$ is higher in Jordan at non-signalised junctions than at signalised junctions and is the same in Sweden. Conversion factors for non-signalised and signalised junctions were three and five times higher in Sweden than Jordan respectively. Although there was a difference, it was not statistically significant. It could be attributed to the two basic issues that constitute these factors, namely the accidents and conflicts.
Accident numbers

The reported number of injury accidents for each type of junction in each country are presented in Table 7.31. It shows that there fewer accidents at non-signalised junctions in Jordan. The variation in the accident numbers is the smallest at non-signalised junctions in Jordan. Both were higher at signalised junctions. Therefore, there is a considerable difference between the reported accident numbers for each type of junction in each country.

Table 7.31 Injury accidents reported by the police at each type of junctions in each country (1993-1997).

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th></th>
<th></th>
<th>Jordan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-signalised junctions</td>
<td>Signalised junctions</td>
<td>non-signalised junctions</td>
<td>Signalised junctions</td>
<td></td>
</tr>
<tr>
<td>Junction number</td>
<td>Accidents</td>
<td>Junction number</td>
<td>Accidents</td>
<td>Junction number</td>
<td>Accidents</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>0</td>
<td>7</td>
<td>1</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>9</td>
<td>2</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>10</td>
<td>2</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td>1.43</td>
<td>1.57</td>
<td>0.38</td>
<td>2.13</td>
<td></td>
</tr>
<tr>
<td>Variation</td>
<td>5.29</td>
<td>0.62</td>
<td>0.24</td>
<td>5.29</td>
<td></td>
</tr>
<tr>
<td>CoV</td>
<td>161</td>
<td>50</td>
<td>130</td>
<td>108</td>
<td></td>
</tr>
</tbody>
</table>

It should be noted that there is the possibility of accident under-reporting. At present, there are no available studies on the extent of this problem in Jordan. Jacobs et al. of the TRL (1986) estimated that underreporting of fatalities in developing countries varies between 25% and 50%. Though due to the accident reporting system in Jordan this may not be the case (Chapter 2.2.1); still it is expected that a large share of injury accidents, especially the slight accidents, would not be reported to the police. In Sweden, the injury accident under-reporting is reaches 41 per cent (CBS, 1983 cited in Hydén and Draskóczy, 1989). A study by Thulin indicated that police reported pedestrian accidents in Sweden should be multiplied by 4.06 have some idea about the real number of accidents; he suggested a factor of 1.37 for vehicle-vehicle accidents (Thulin, 1987 cited in Hydén and Draskóczy, 1991).

Conflict frequency and distribution over severity grades.

Conflict frequency expressed as the number of conflicts per hour is presented in Table 7.32. It indicates that conflicts were generally more frequent at signalised junctions compared to non-signalised junctions in each country. Conflict frequency for signalised
junctions in Jordan was almost twice that in Sweden and it was 1.5 times for signalised
junctions.

Table 7.32  Conflict frequency for each junction type

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Serious conflicts per hour “Present definition of RRU”</th>
<th>Serious conflicts per hour “High definition of RRU”</th>
<th>All Conflicts per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden-Non-Signalised-junctions</td>
<td>1.6</td>
<td>2.9</td>
<td>3.70</td>
</tr>
<tr>
<td>Sweden-Signalised-junctions</td>
<td>1.7</td>
<td>3.6</td>
<td>5.19</td>
</tr>
<tr>
<td>Jordan-Non-Signalised-junctions</td>
<td>2.3</td>
<td>5.2</td>
<td>5.54</td>
</tr>
<tr>
<td>Jordan-Signalised-junctions</td>
<td>5.8</td>
<td>9.4</td>
<td>10.40</td>
</tr>
</tbody>
</table>

The frequency of the recorded serious conflicts at signalised junctions and non-signalised
junctions in Jordan were 55.8% and 42% respectively. This was compared to 32.7% and
43% in Sweden. This might imply that the safety situation is different in the two
countries when junction type is taken into account. Signalised junctions seem to be more
hazardous in Jordan as indicated by the accident number and the proportion of recorded
serious conflicts.

Svensson (1998) indicated that it is not only interesting to analyse the situations that
described the most severe situation conflicts (serious conflicts). Other situations, like
interactions are believed to add to our understanding of the traffic safety process. She
added that the distribution of interactions over severity grade should be of major concern
for a safety analyst in their evaluation. Distributions that are perceived to reflect safe
conditions are those of wide convexity and shifted toward the moderate severe grades
(zones) of conflicts. Convexity describes that part of conflict distribution where most
interactions are located. She also suggested that a threshold borderline could be drawn
below which interactions in traffic would promote safety if they are not of high severity
which according to Svensson is the present threshold GR5. It is believed that if road-users
become involved in rather serious situations more frequently, they would learn to avoid
the most serious ones including accidents.

Conflict distributions over severity grade for each type of junction in each country are
presented in Figure 7.3. The conflict distribution over severity grade at signalised
junctions in Jordan, shown in Figure 7.3, is characterised by a wide convexity. It is shifted
beyond the threshold borderline that was suggested by Svensson (1998) and this indicates
unfavourable conditions for safety. The road-users in Jordan are exposed to many severe
situations, which are above the threshold borderline proposed by Svensson and still they
seem to learn avoiding the most severe of these situations. This is indicated by the low
values of accidents to conflict conversion factors in Jordan. On the other hand, accident
under-reporting may attribute to report only few number of accidents.
Figure 7.3 Conflict distribution over severity grade for each type of junction in each country; conflict severity was defined based on the present RRU definition.

The convexity of conflict distribution at signalised junctions (Figure 7.3) in Sweden is narrower than Jordan's distribution and they show a shift toward less severe grades of conflicts. This might create unsafe conditions, which would explain why the conversion factors developed for signalised junctions in Sweden were higher than those in Jordan.

The convexity of the conflict distribution for non-signalised junctions in Sweden is wide and shifted towards lower severity grades. Conflicts recorded in Jordan produced a convexity, which is wider and slightly shifted towards high severity grades. In fact there is a similarity between the two distributions. Conflicts distribution in Jordan resembles the distribution of conflict over severity grades for non-signalised junctions in Sweden but enlarged by a factor of 1.4. The recorded conflicts in Jordan were related to a smaller number of accidents, which then produces smaller conversion factors.

Although the distributions look different, K-S test results failed to demonstrate that there is any significant difference between conflict distributions over severity grade between the two countries for either non-signalised or signalised junctions.

Conflict distributions were also investigated by considering the traffic exposure (Figure 7.4). Conflict rates were calculated by dividing the conflict numbers by the sum product of pedestrian-vehicle traffic streams, which was selected as a measure of exposure. This measure of exposure was selected because it takes into account both the volumes of pedestrians and vehicles that are interacting at the selected junctions.
Figure 7.4 Conflict rate distribution over severity grade for each type of junction in each country expressed by conflict number by the sum product of pedestrian-vehicle traffic streams as a measure of exposure.

The same trend that was reported when the exposure was not taken into consideration was apparent when the distributions were related to the exposure. Figure 7.4 suggest that the conflict rate is much smaller in Sweden at signalised junctions than in Jordan and the number of conflicts when related to the exposure is much lower in Sweden than it is in Jordan. Conflicts are not frequent at signalised junctions, which are characterised by high traffic volume. This might create unsafe conditions at thus type of junction. Figure 7.4 also indicates that the convexity of conflict rate distribution is wider for signalised junctions in Jordan when compared to that of signalised junctions in Sweden. Furthermore, it is shifted towards the higher severity grades.

Figure 7.4 suggests that conflict rate is relatively high in Sweden; conflicts are frequent at non-signalised junctions that have low traffic volume. The convexity of the distribution is wider than its corresponding in Jordan; it is shifted towards less severe grade. However, the difference between the two distributions is small. Besides, K-S test failed to show any significant difference between the two distributions. The results could be explained by the fact that the traffic volume is low at non-signalised junctions in Sweden as shown in Table 7.33. In addition the pedestrian volumes are lower at this type of junction and subsequently encounters with pedestrians do not often occur. This might encourage high vehicle speed and if traffic conflicts happen, then the probability of injury accidents would be high had no road-user acted to end the conflicts.
Table 7.33 The average daily traffic volume for each type of junction in each country.

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Vehicle entry volume ¹</td>
<td>Pedestrian Inflow ²</td>
</tr>
<tr>
<td>Non-signalised</td>
<td>14.7</td>
<td>8.87</td>
</tr>
<tr>
<td>Signalised</td>
<td>36</td>
<td>10.38</td>
</tr>
</tbody>
</table>

¹ Total vehicle entry volume: the sum of all vehicles entering the junction
² Pedestrian in flow: the sum of all pedestrians crossing all junction approaches

In Jordan, the traffic volumes at non-signalised junctions are higher than in Sweden and the pedestrian volumes are also slightly higher. Encounters with pedestrians are therefore more likely in Jordan. A high traffic volume of pedestrians and vehicles is expected to produce a high number of conflicts. However, high traffic volumes result in a reduction in vehicle speed, which then leads to conflicts with less probability of producing injury accidents. This is indicated from the low number of accidents (Table 7.31). Accordingly the accident to conflict conversion factors become smaller.

To conclude accidents, traffic volumes, conflicts and their distributions were different in the two countries. These three factors interplay together in developing the accident to conflict conversion factors for the junctions under scrutiny.
8 Road-user perception of conflicts

The difference between the road-user behaviour in the two countries is expected to be a reflection of the existing differences between the two traffic environments. The influence of this difference on the road-users’ perception of conflict characteristics including their severity was investigated in verifying Hypothesis 3, which states:

Hypothesis 3: Conflict characteristics and their perception are different in the two countries.

The third hypothesis was investigated from three perspectives, including:

1. Examining the difference between conflict characteristics recorded in Sweden and Jordan.
2. Investigating how the road-users involved in conflicts perceived these situations and assessed their severity.
3. Exploring how laymen coming from different traffic environments would assess the severity of conflicts that involved other road-users and were recorded in different traffic environments than their own.

The verification of Hypothesis from each perspective will be presented in the following section.

8.1 Conflict characteristics

The analysis of conflict characteristic differences between the two countries was based on the following main aspects:

- The relevant road-user type
- The type of evasive action made and its characteristics
- Speed and TA characteristics of the recorded conflicts

8.1.1 Relevant road-user type analysis.

The present definition of relevant road-user (RRU) was the basis for defining the RRU in this analysis. It was chosen because performing some sort of evasive action is the cornerstone in defining conflict severity in the present Swedish TCT. Taking evasive action is still used in defining the severity of conflicts that were based on the high or the low definition of RRU, but it is not used as a criterion for defining the RRU. In addition, the present definition is the one currently used in practice.
The RRU issue was investigated by considering some aspects that are expected to influence which road-user would be the RRU in each country. The broad theme for the analysis is summarised in Sub-Hypothesis (3-A).

**Sub-Hypothesis (3-A):** The relevant road-user type defined according to the present definition varies according to the country under study.

Conflict data was analysed to define the proportion of each of road-user type that was considered as the RRU. Primarily two categories of road-user types were considered, the vehicles and pedestrians. The number and percentage of relevant road-users by road-user type in each country are presented in Table 8.1.

**Table 8.1** Number of road-users, which are categorised by their types, and their proportions as RRU.

<table>
<thead>
<tr>
<th>Road-user type</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td>1126 (85%)</td>
<td>745 (56%)</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>197 (15%)</td>
<td>590 (44%)</td>
</tr>
<tr>
<td>All conflicts</td>
<td>1323 (100%)</td>
<td>1335 (100%)</td>
</tr>
</tbody>
</table>

The results indicate that there is quite a considerable difference between the two countries. The proportion of pedestrians as RRU in Jordan (44%) is almost three times as in Sweden (15%). The main conclusion that could be drawn from this is that pedestrians in Jordan tend to take evasive actions to avoid the consequence of being involved in conflicts more than Swedes do. On the contrary, it could be that the driver in Jordan declines to perform evasive actions and forces the pedestrian to do it him/herself.

The Jordanian drivers more frequently take evasive action if they were involved in severe situations. The Swedish drivers tend to take evasive action even if they were involved in less severe conflicts (Figure 8.1). Pedestrians in Jordan took evasive action when they were involved in severe situations. There is no clear link between the conflict severity and the tendency of the Swedish pedestrians to take evasive actions. They acted if they were involved in less severe or if they were involved in more severe conflicts, particularly at signalised junctions.
Figure 8.1.1 Conflict severity distribution for situations involving drivers taking evasive actions.

Figure 8.1.2 Conflict severity distribution for situations involving pedestrians taking evasive actions.

The breakdown of the vehicle driver category as RRU by type of vehicle involved is presented in Table 8.2. The results indicated that there are considerable differences between the two countries. Private car drivers compose the highest proportion (>80%) of the drivers that are claimed to be the RRU in Sweden. The corresponding proportion in Jordan is 51 per cent. Apart from the private car drivers as RRU, other vehicle drivers in Sweden are equally presented as RRU and their proportion is around one fifteenth of the vehicle driver category. On the contrary, data from Jordan indicated that proportion of taxi drivers (22%) as RRU almost equals the proportion of van/pickup drivers (20%). Whereas lorry and bus driver proportion does not exceed one tenth of all vehicle driver category.
Table 8.2  The proportion of each vehicle driver type of that were classified as RRU, expressed as a percentage out of all vehicle drivers in each country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Private car</th>
<th>Taxi</th>
<th>Van/ Pickup</th>
<th>Bus/ Lorry</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>83</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Jordan</td>
<td>51</td>
<td>22</td>
<td>20</td>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

The noticeable difference in vehicle type distribution is attributed to the fact that the traffic composition is different in the two countries. The traffic composition averaged over the selected junctions regardless of the junction type is presented for each country in Table 8.3.

Table 8.3  Average traffic composition in Sweden and Jordan expressed as a percentage out of all vehicle types in each country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Private car</th>
<th>Taxi</th>
<th>Van/ Pickup</th>
<th>Bus/ Lorry</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>78</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>Jordan</td>
<td>38</td>
<td>30</td>
<td>22</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

Since the data presented in Table 8.3 are for all types of junctions, the comparison with Table 8.2 is also made for all junction types together. The overall results indicated that there is a close agreement between the traffic volume composition and the proportion of the drivers of each vehicle type that were defined as RRU when being involvement in conflicts.

The car drivers in Jordan are over-represented in conflicts as RRU compared to their actual involvement in traffic. The proportion of private car driver as RRU is 51 per cent while they compose only 38 per cent of the traffic. Taxi, lorry and bus drivers one the other hand, are under-represented in conflicts as RRU compared to their actual involvement in traffic.

The last finding might be linked to the assumption that conflict involvement is related to the driver proficiency level. Private car drivers are less experienced, less professional than taxi or bus drivers, so they are expected to have a higher level of involvement in conflicts and if they are involved, at least in Jordan, they tend to take action. Thus, the representation will be higher as RRU. On the other hand, the taxi, lorry and bus drivers are professional drivers and they either manage not to be involved in conflicts or if they are involved in conflicts they are reluctant to take action. Pedestrians took action once they were involved in conflicts with drivers of these types of vehicles, particularly the
lorries or buses. Thus, their presence as relevant road-users would be different from their general presence in traffic.

In conclusions, there is a difference between the type of RRU in the two countries. The drivers are more frequently the relevant road-users in Sweden, particularly the private passenger car driver while pedestrians are more frequently reported as RRU in Jordan. Other types of vehicle drivers, including taxi, van/pickup, are rarely reported as RRU in Sweden. In Jordan, the taxi drivers and the pickup drivers are almost equal in their proportions (20%) of RRU’s.

8.1.2 The type of evasive action and its characteristics

Since the type of RRU appears to be different in the two countries, it also expected that the type of evasive action made and its characteristics would be different between Sweden and Jordan. Sub-hypothesis (3-B) was formulated as follows:

Sub-Hypothesis (3-B): The type of evasive action made and its characteristics differ due to country.

The types of evasive actions performed by either the driver or the pedestrian were observed during the conflict recording. In addition, two important characteristics of the evasive actions received considerable attention:

- The suddenness of the action.
- The decisiveness of the action.

Type of evasive action

The results of investigating the relationship between the type of action and the type of road-user in each country is presented in Table 8.4.
Table 8.4 The proportion the road-users who did or did not perform evasive action out of the total number of observed conflicts for each type of road-user at each type of junction. The proportion for each observed action out of the total number of observed actions.

<table>
<thead>
<tr>
<th>Country</th>
<th>Junction type</th>
<th>Number of conflicts</th>
<th>Performing the action</th>
<th>Type of action</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No Action</td>
<td>Action</td>
<td>Braking</td>
<td>Swerving</td>
<td>Accelerating</td>
<td>Braking-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Sweden</td>
<td>Non-signalled</td>
<td>443</td>
<td>16</td>
<td>3.6</td>
<td>427</td>
<td>96.4</td>
<td>417</td>
<td>97.7</td>
</tr>
<tr>
<td></td>
<td>Signalised</td>
<td>880</td>
<td>60</td>
<td>6.8</td>
<td>820</td>
<td>93.2</td>
<td>792</td>
<td>96.5</td>
</tr>
<tr>
<td>Jordan</td>
<td>Non-signalled</td>
<td>442</td>
<td>96</td>
<td>21.7</td>
<td>346</td>
<td>78.3</td>
<td>297</td>
<td>85.8</td>
</tr>
<tr>
<td></td>
<td>Signalised</td>
<td>893</td>
<td>186</td>
<td>20.8</td>
<td>707</td>
<td>79.2</td>
<td>635</td>
<td>89.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Junction type</th>
<th>Number of conflicts</th>
<th>Performing the action</th>
<th>Type of action</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No Action</td>
<td>Action</td>
<td>Stopping</td>
<td>Stepping a side or backward</td>
<td>Running</td>
<td>Stopping &amp; stepping a side or backward</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Sweden</td>
<td>Non-signalled</td>
<td>443</td>
<td>363</td>
<td>81.9</td>
<td>80</td>
<td>18.1</td>
<td>36</td>
<td>45.0</td>
</tr>
<tr>
<td></td>
<td>Signalised</td>
<td>880</td>
<td>697</td>
<td>79.2</td>
<td>183</td>
<td>20.8</td>
<td>78</td>
<td>42.6</td>
</tr>
<tr>
<td>Jordan</td>
<td>Non-signalled</td>
<td>442</td>
<td>198</td>
<td>44.8</td>
<td>244</td>
<td>55.2</td>
<td>82</td>
<td>33.6</td>
</tr>
<tr>
<td></td>
<td>Signalised</td>
<td>893</td>
<td>431</td>
<td>48.3</td>
<td>462</td>
<td>51.7</td>
<td>144</td>
<td>31.2</td>
</tr>
</tbody>
</table>

The results indicated braking only is the most frequent type of evasive action taken by vehicle drivers in Sweden. Other evasive actions are very rare in Sweden. On the other hand, while braking only is the most frequent type of evasive action made in Jordan, other types of actions were reported, such as combined action of braking and swerving. It is expected that the driver would not take more than one type of evasive action at the same time unless the situations are serious. It was reported earlier that the Jordanian drivers acted evasively when they were involved in severe situations while Swedish driver tend to take evasive action even if they were involved in less severe situations.

There are similarities between type of evasive actions made by pedestrians in the two countries. Pedestrians seem to run quite often to escape the danger of being involved in conflicts, particularly at signalised junctions; alternatively, they stopped if they could. However, it should be noted that pedestrians in Jordan tend to take more than one action while avoiding the consequence of being involved in conflicts particularly at non-signalised junctions, which is not so frequent in Sweden.
If we look at action by pedestrian against action by vehicle driver, we note that once a Jordanian driver took action some of the pedestrians would still take evasive action. The Swedish pedestrians, however, tend to rely on the driver to solve the conflicts.

Overall, there are similarities between the type of evasive action made in the two countries. However, it was noted that Jordanian pedestrians and drivers tend to combine more than one evasive action, which is not common in Sweden.

**Characteristics of evasive actions**

The descriptions of evasive actions made by each road-user in each country are presented in Table 8.5.

**Table 8.5** The characteristics of each evasive action made by either the driver or the pedestrian. They are presented as absolute numbers and as proportions of the total number of observed evasive actions reported at each type of junction in each country.

<table>
<thead>
<tr>
<th>Driver evasive action characteristics</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-signalised junctions</td>
<td>Signalised junctions</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Decisiveness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hesitant</td>
<td>120</td>
<td>28</td>
</tr>
<tr>
<td>Decisive</td>
<td>307</td>
<td>72</td>
</tr>
<tr>
<td>All conflicts</td>
<td>427</td>
<td>100</td>
</tr>
<tr>
<td>Suddenness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Sudden</td>
<td>286</td>
<td>67</td>
</tr>
<tr>
<td>All conflicts</td>
<td>427</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pedestrian evasive action characteristics</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-signalised junctions</td>
<td>Signalised junctions</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Decisiveness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hesitant</td>
<td>25</td>
<td>31</td>
</tr>
<tr>
<td>Decisive</td>
<td>55</td>
<td>69</td>
</tr>
<tr>
<td>All conflicts</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Suddenness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Sudden</td>
<td>49</td>
<td>61</td>
</tr>
<tr>
<td>All conflicts</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

The driver’s action characteristics indicate that Swedish drivers are more decisive in taking their evasive actions than Jordanian drivers. The Swedish drivers’ actions are characterised by being decisive but not sudden. It is as if the driver in Sweden is prepared to act to solve
the conflict, not leaving the decision to the pedestrian instead. In Jordan, particularly at signalised junctions, the drivers are hesitant to take evasive action. They might be looking to gain time at signals so they become hesitant to act to make the best use of the available green.

Swedish and Jordanian pedestrians acted decisively and suddenly. But, the proportion of their actions could be described as higher in Jordan than in Sweden. This finding might be explained in two ways. Firstly, the pedestrian feels the threat much closer to her/him than the driver so if she/he felt that they would act strongly to escape it. Secondly, the pedestrian might have waited for the driver to take the action and since she/he did not or did it lately the pedestrian needed to act suddenly and decisively to escape the danger involved in the conflicts concerned.

In general, there are similarities between the evasive action characteristics reported in the two countries.

### 8.1.3 Speed and TA characteristics of the recorded conflicts

Conflict severity within the Swedish TCT is determined by considering the conflicting speed and the TA-values. Investigating similarities or differences between two sets of conflict data should take into account these characteristics as a vital part of the comparison. Based on conflict severity assessment, it might be possible to formulate the following two sub-hypotheses:

**Sub-Hypothesis (3-C):** The conflicting speed differs according to the country concerned.

**Sub-Hypothesis (3-D):** The time remaining to accident differs according to the country concerned.

The conflicting speeds of the vehicle driver and the pedestrians were assessed as part of the normal routine for conflict detection and severity rating. They were averaged for each type of junction in each country and the results are presented in Table 8.6.
Table 8.6  The mean conflicting speed to accidents assessed for the vehicle driver speed and for the pedestrians that were involved in conflicts. Assessments were made for each type of junction in each country.

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Country</th>
<th>Road-user type</th>
<th>Mean (Km/h)</th>
<th>Standard Deviation (Km/h)</th>
<th>Minimum (Km/h)</th>
<th>Maximum (Km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-signalised</td>
<td>Sweden</td>
<td>Driver</td>
<td>22.61</td>
<td>7.82</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>5.31</td>
<td>0.91</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Jordan</td>
<td>Driver</td>
<td>22.40</td>
<td>10.16</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>5.22</td>
<td>1.37</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Signalised</td>
<td>Sweden</td>
<td>Driver</td>
<td>20.01</td>
<td>6.83</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>5.43</td>
<td>1.33</td>
<td>3.2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Jordan</td>
<td>Driver</td>
<td>19.01</td>
<td>8.97</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>5.16</td>
<td>1.37</td>
<td>0</td>
<td>15</td>
</tr>
</tbody>
</table>

There are no considerable differences between countries in conflicting speeds; still the 1 km/h difference in driver speed at signalised junctions was statistically significant. The variation of speeds is higher in Jordan than in Sweden. These findings might provide support to verify hypothesis (3-C) and yet it is weak. They indicate that the speeds in Sweden are higher than in Jordan. That could be explained by the fact that the infrastructure in Sweden is developed so as it could facilitate higher and more uniform speed than the poor infrastructure in Jordan. Besides, the complexity of traffic situation, which is a reflection of the exposure in traffic, is higher in Jordan, thus the drivers slow down and the mean speed is reduced.

In fact, the complexity of traffic conditions in the two countries revealed that both drivers and pedestrians in Jordan are subjected to more complex situations than Swedish drivers or pedestrians. Analysis of variance test (ANOVA) indicated that there is significant difference in the traffic exposure indices that were developed to reflect the complexity of traffic situations measured few seconds before the conflicts.

The time remaining to accident is a fundamental concept in defining conflict severity, which is normally assessed as part of the normal routine for conflict detection and severity rating. TA-value for each road-user type were averaged for each type of junction in each country and the results are presented in Table 8.7.
Table 8.7 The time remaining to accidents (TA-value) assessed for the vehicle driver and for the pedestrians that were involved in conflicts; assessments were made for each type of junction in each country.

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Country</th>
<th>Road-user type</th>
<th>Mean (Sec)</th>
<th>Standard deviation (Sec)</th>
<th>Minimum (Sec)</th>
<th>Maximum (Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-signalised</td>
<td>Sweden</td>
<td>Driver</td>
<td>1.12</td>
<td>0.32</td>
<td>0.20</td>
<td>2.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>1.03</td>
<td>0.44</td>
<td>0.15</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>Jordan</td>
<td>Driver</td>
<td>0.89</td>
<td>0.41</td>
<td>0.10</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>0.66</td>
<td>0.38</td>
<td>0.12</td>
<td>2.90</td>
</tr>
<tr>
<td>Signalised</td>
<td>Sweden</td>
<td>Driver</td>
<td>1.16</td>
<td>0.34</td>
<td>0.18</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>0.92</td>
<td>0.43</td>
<td>0.15</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Jordan</td>
<td>Driver</td>
<td>0.85</td>
<td>0.41</td>
<td>0.10</td>
<td>3.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>0.64</td>
<td>0.35</td>
<td>0.07</td>
<td>2.20</td>
</tr>
</tbody>
</table>

The driver’s mean TA-values at both non-signalised and signalised junctions in Jordan are lower, Table 8.7 than their corresponding values in Sweden. The variations around the mean values in Jordan were higher. The ANOVA test indicated that the difference is statistically significant.

The pedestrian mean TA-value was also lower in Jordan regardless of being estimated at non-signalised or signalised junctions. The variation around the mean was also lower for both types of junctions. Moreover, the ANOVA test demonstrated that there is a significant difference between the estimated TA-values in the two countries.

Thus, the Sub-Hypothesis (3-D) is verified indicating that TA-values were lower in Jordan reflecting the close proximity between the involved road-users.

Figure 8.2 shows the average conflict severity estimated based on average speed and the average TA-value for the driver each road-user type each type of junction in each country. The average TA-value versus the average pedestrian speed for each country is only shown for signalised junctions.
Figure 8.2  Conflict severity based on the average speed and TA-value estimated for drivers and pedestrians in the two countries.

Figure 8.2 shows that although the speed is on average slightly lower in Jordan, the average TA-value is also lower in Jordan indicating that the conflicts are more serious in Jordan compared to Sweden. There is difference between the estimated TA-values for pedestrian and the driver, which is hypothetically, should be the same. It may attribute to the fact that the pedestrian distance to the potential accident point could be at any point along the car width, which makes its estimation subjected to the observer’s subjective assessment. Adding to this that the observations were made from videotapes, which makes the assessment more problematic.
Conclusions

♦ Proportion of pedestrians, as RRU is higher in Jordan. The proportion of Jordanian pedestrians that tend to take evasive is higher than their Swedish counterparts.

♦ Jordanian drivers performed less evasive action than Swedish drivers did. Drivers brake more often to solve the conflicts they were involved in while the pedestrians run to escape the threat they were exposed to. Swedish drivers were more decisive in taking their actions than Jordanian drivers were. There is no difference between pedestrian evasive action characteristics in the two countries.

♦ Conflicting speed for both the drivers and the pedestrians was slightly higher in Sweden with less variation, which might be attributed to the difference in traffic situation complexity in the two countries. Jordanian drivers and pedestrians are exposed to more complex situations in traffic than Swedish drivers and pedestrians.

♦ The driver mean TA-values either at non-signalised junctions or at signalised junctions in Jordan are lower than their corresponding values in Sweden. The variations around the mean values in Jordan were higher. The pedestrian mean TA-value, regardless of being estimated at signal or non-signal junctions, was also lower in Jordan but the variation around the mean is smaller.

♦ Conflicts on average are more severe in Jordan than in Sweden.
8.2 Road-users perception of conflict severity

Road-users involved in conflicts might have been involved unintentionally and they did not recognise them. They might recognise conflicts but would not perceive them as severe as the conflict observer does or vice versa. Road-user assessment of conflict severity is a reflection of their perception of the risk, which reflects their feeling of danger in traffic, they are subjected to while being involved in conflicts. A number of pedestrians in the two countries were interviewed according to an interview form shown in Appendix B-3. Their responses were analysed with respect to their perception of conflict severity as well as their perception of what conflicts are, as they were asked to describe what they experienced during their involvement in conflicts.

8.2.1 Conflict recognition and severity rating

The tested sub-hypothesis is

Sub- Hypothesis (3-E): Pedestrians perceive the severity of conflicts they have been involved in differently in each country.

The verification of this sub-hypothesis was based on two aspects, namely:

- The road-users recognition of being involved in conflicts.
- The road-users assessment of conflict severity.

Conflict recognition

Table 8.8 shows the proportion of pedestrians who recognised being involved in conflicts in the two countries.

Table 8.8 The number and the proportion of pedestrians who recognised as being involved in conflicts in the two countries.

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th></th>
<th></th>
<th>Jordan</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Of which is</td>
<td>Number</td>
<td>%</td>
<td>Of which is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>serious</td>
<td></td>
<td></td>
<td>serious</td>
</tr>
<tr>
<td>Recognised</td>
<td>40</td>
<td>40</td>
<td>37</td>
<td>61</td>
<td>69</td>
<td>75</td>
</tr>
<tr>
<td>Not-recognised</td>
<td>59</td>
<td>60</td>
<td>43</td>
<td>28</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>All interviewees</td>
<td>99</td>
<td>100</td>
<td></td>
<td>89</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

According to Table 8.8 the proportion of pedestrians who recognised being involved in conflicts is higher in Jordan than in Sweden. This might be an indication that the road-users, the pedestrians in this case, perceive risk differently. They are exposed to different
driving conditions that influence their perception of different events in traffic and their behaviour.

For instance, the severity of conflicts the pedestrians in Jordan were exposed to was higher than the severity of conflicts recorded in Sweden, Figure 8.3. Serious conflicts in Sweden compose around one third of the recorded conflicts that were defined by considering the present threshold GR5. The corresponding proportion in Jordan is 70 per cent, which is more than twice the reported in Sweden. Serious conflicts are unpleasant events that are recognised more often than other types of events (Hydén, 1987). This makes the Jordanian pedestrians more likely to recognise conflicts since the conflicts were more serious in Jordan. The pedestrians in Sweden were able to recognise 37 per cent of all the recorded serious conflicts in Sweden while Jordanian pedestrians recognised 75 per cent of all recorded serious conflicts in Jordan.

![Graph showing conflict severity distribution]

**Figure 8.3** Conflict severity distribution (present Swedish TCT definition) for those conflicts where the involved road-users were interviewed in the two countries.

Road-users in the two countries are behaving differently in traffic. It is a reflection of their perception of danger. Pedestrians in Jordan are more likely to take evasive action to avoid the consequences of being involved in conflicts. It is expected that unless the pedestrians recognise the conflict they would not act evasively. The relationship between conflict recognition and performing evasive action are presented in Table 8.9.
The numbers and the proportion of pedestrians that acted evasively out of all road-users who recognised their involvement in conflicts. Information about pedestrians that did not act evasively and recognised the conflicts is included. Similar data is also provided for pedestrians that did not recognise their involvement in conflicts.

<table>
<thead>
<tr>
<th>Conflict recognition</th>
<th>Sweden</th>
<th></th>
<th>Jordan</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acted evasively</td>
<td>Did not act evasively</td>
<td>Total (A+NA)</td>
<td>Acted evasively</td>
<td>Did not act evasively</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>% A</td>
<td>Number</td>
<td>% NA</td>
<td>%</td>
</tr>
<tr>
<td>Recognised</td>
<td>17</td>
<td>43</td>
<td>23</td>
<td>57</td>
<td>100</td>
</tr>
<tr>
<td>Not-recognised</td>
<td>14</td>
<td>24</td>
<td>45</td>
<td>76</td>
<td>100</td>
</tr>
</tbody>
</table>

1) Proportion of pedestrian who acted evasively  2) Proportion of pedestrian who did not act evasively.

The proportion of pedestrians who recognised their involvement in conflicts and performed evasive actions is three times the proportion of pedestrians who recognised the conflicts but did not take evasive action (Table 8.9). On the other hand, the proportion of Swedish pedestrians who acted evasively and recognised their involvement in conflicts is lower than the proportion of those that did not act evasively and did not recognise the conflicts. This implies that the largest portion of pedestrians that recognised their involvement in conflicts in Sweden did not act.

This apparent difference between the countries might be attributed to the fact that recorded conflicts were not so serious in Sweden; alternatively, it could be different behaviour in traffic. As said before, pedestrians in Sweden are more reluctant to take evasive action and trust that the drivers should act, which is not the case in Jordan.

To conclude, Jordanian pedestrians recognised the conflicts more than the Swedish pedestrians. Jordanians acted evasively to solve the consequences of being involved in conflict more often than the Swedish pedestrians, who tend to rely on the drivers.

Conflict severity rating

The interviewed pedestrians were asked to answer question number 6 in the interview form, B-3 (“How serious do you think the situation has been?) The response to this question was 75 per cent in Sweden and 93 per cent in Jordan.

The responses to this question that measure the pedestrian subjective severity ratings were compared to the estimated conflict severity. The aim is to explore agreement between pedestrians’ subjective severity rating with the estimated severity of conflicts (Table 8.10).
Table 8.10  The proportions of recognised conflicts that were rated slight or serious by both the interviewed pedestrians and the conflict observer. In addition, the proportions of recognised conflicts that were rated slight by the interviewed pedestrians while as serious by the conflict observer and vice versa.

<table>
<thead>
<tr>
<th></th>
<th>Slight</th>
<th></th>
<th>Serious</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agreement</td>
<td>Disagreement</td>
<td>Agreement</td>
<td>Disagreement</td>
</tr>
<tr>
<td></td>
<td>SL-SL %</td>
<td>SL-SR %</td>
<td>SR-SL %</td>
<td>SR-SR %</td>
</tr>
<tr>
<td>Sweden</td>
<td>30</td>
<td>70</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Jordan</td>
<td>57</td>
<td>23</td>
<td>77</td>
<td>27</td>
</tr>
</tbody>
</table>

SL-SL: Interviewed pedestrian rating is slight-Observer rating also slight.
SL-SR: Interviewed pedestrian rating is serious-Observer rating is slight.
SR-SL: Interviewed pedestrian rating is slight-Observer rating, contrarily, is slight.
SR-SR: Interviewed pedestrian rating is slight -Observer rating is also serious.

Table 8.10 suggests that the agreement between the two ratings was slightly higher for slight conflicts recorded in Sweden compared to the serious conflicts rating. The agreement between the two ratings was much higher for serious conflicts recorded in Jordan compared to slight conflicts.

Swedish pedestrians have a tendency to rate the severity of conflicts at low levels (slight), while the Jordanians have the opposite. The noticeable difference in their subjective severity assessment could be a reflection of their different perception of risk. It might be that the Swedish pedestrians expect a safe traffic environment with minimal danger or threat. They perceive the conflicts they were involved in as slight and under control, so they did not even act. On the other hand, Jordanian pedestrians expect unsafe traffic environment. This was reflected on their assessment and their actions.

In conclusion, pedestrians’ perception of conflict severity is different in the two countries.

8.2.2 Pedestrians’ description of conflicts

The tested sub-hypothesis was

Sub-Hypothesis (3-F): Pedestrians in the two countries describe their involvement in conflicts differently.

All pedestrians that recognised their involvement in traffic conflicts in Sweden were asked the question "Can you describe what has happened". The response rate for this question in Sweden was 100 per cent while the corresponding rate in Jordan is 85 per cent. The pedestrians’ answers were rather short, although the interviewers pushed hard to obtain more details. The answers were coded and similar answers were grouped together in 12 categories as shown in Table 8.11.
Table 8.11  Pedestrians description of the conflicts they have been involved in.

<table>
<thead>
<tr>
<th>Description of the situation</th>
<th>Sweden</th>
<th></th>
<th></th>
<th>Jordan</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
<td>Percent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description of wrong event</td>
<td>4</td>
<td>10</td>
<td></td>
<td>7</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>Right of way ROW</td>
<td>13</td>
<td>32.5</td>
<td></td>
<td>1</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Traffic rule compliance</td>
<td>8</td>
<td>20</td>
<td></td>
<td>2</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>Fast driving and ROW</td>
<td>5</td>
<td>12.5</td>
<td></td>
<td>5</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Taking evasive action</td>
<td>4</td>
<td>10</td>
<td></td>
<td>3</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Not knowing who has the ROW</td>
<td>3</td>
<td>7.5</td>
<td></td>
<td>8</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td>Almost hit by a car</td>
<td>1</td>
<td>2.5</td>
<td></td>
<td>4</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>Miss understand the question</td>
<td>2</td>
<td>5</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Being in a hurry</td>
<td>4</td>
<td></td>
<td></td>
<td>7.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Being no attention/ talking to a friend</td>
<td>12</td>
<td>23.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design problems</td>
<td>3</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal situation</td>
<td>3</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>40</td>
<td>100</td>
<td></td>
<td>52</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The results as shown in Table 8.11 indicates that one fifth of the interviewed pedestrians in Sweden described the event not as conflicts but as a traffic rule compliance. For example, pedestrians tend to say that the driver should have stopped when approaching a pedestrian crossing. They seem to have high expectation at the crossing and the driver is the one that should give the right of way. On the other hand, around one third of the interviewed pedestrians referring to conflict as synonym to the driver disregarding the pedestrian "right of way" at the crossing. Furthermore, the right of way concept also appeared in another group of answers but combined with fast driving. The vast majority of pedestrian answers in Sweden were describing the conflict as an issue that is related to the right of way (65 per cent of all responses to this question). They expect that they should be given the right of way. If they were not given it then the drivers did not abide by the rules.

The responses reported in the interviews in Jordan appeared to be different from those reported in Sweden; thus, indicating different attitude to traffic. While the right of way was at the core of all answers reported in Sweden this was not the case for the answers given in Jordan. Only few pedestrians were referring to the right of way and even some of them did not know who has the right of way. The right of way concept is not clear to the pedestrians, otherwise it should have been reflected in their answers. This maybe due to the poor traffic-rule education.
The proportion of those who described a different event was slightly higher in Jordan. This could be explained by the fact that the selected junction is Jordan is rather more complex than that one in Sweden. Many events happened at the same time and with varying degrees of severity. Alternatively, it could be that the pedestrians were involved in more than one conflict while crossing. This was observed to happen in Jordan.

The most interesting result reported from the interviews in Jordan was that those who were involved in a conflict without noticing it represented 23 per cent of all the interviewed pedestrians. Some pedestrians stated that they were in a hurry (another form of saying that they were not being attention to traffic). Around one-third (31%) of the pedestrians involved in conflicts in Jordan did not notice what has happened and considered these situations as normal.

The responses of the pedestrians to question number 17, “In your opinion, who triggered the incident and how?” were also investigated to clarify the pedestrian perspective on who has initiated the conflicts (Table 8.12).

<table>
<thead>
<tr>
<th>Table 8.12</th>
<th>Pedestrians’ responses for the question (“In your opinion, who triggered the incident and how?”).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conflicts from Sweden</td>
</tr>
<tr>
<td></td>
<td>No body</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>36%</td>
<td>8%</td>
</tr>
</tbody>
</table>

The results from the interviews made in Sweden showed that the pedestrians’ responses fell into three categories (nobody, own, and driver). They were more definite answers than those in Jordan. The answers to this question in Jordan were more diverse and were coded into six categories (nobody, own, driver, both, no rules applied, and no comments). The majority of responses in Sweden indicated that pedestrians believe that the drivers had initiated the conflicts. More than half (56%) of the interviewed pedestrians blamed the drivers. Only 8 per cent thought that they have initiated the conflicts themselves. Interestingly, some pedestrians believed that nobody should be blamed for causing the conflicts. This could be attributed to the fact that some of the selected conflicts were slight ones.

Table 8.12 has shown that the answers from Jordan indicated that pedestrians blamed themselves in the first place for being involved in conflict (either as solely responsible or share the responsibility with the driver). This should be read in line with the fact that pedestrians in Jordan recognised their involvement in conflicts and acted evasively to avoid the consequence of being involved in conflicts, which is not the case in Sweden. The low level of awareness of traffic rules is another perspective that should be considered in the interpretation. Thirteen per cent of all respondents indicated that no rules applied in these situations. This emphasised the low level of awareness among pedestrians in
Jordan. Only one quarter of all responses demonstrated that the pedestrians believed that
the drivers are responsible for the conflict. This percentage is half the percentage recorded
in Sweden, where the pedestrians strongly believed that they have the right of way.
Although, it is by law that pedestrians should have the priority in Jordan. Yet, in reality
they have the least priority and they start to act accordingly hence, they blamed
themselves and pardoned the drivers.

To sum up, pedestrians in the two countries described the conflicts in different terms.
The right of way was the most common term used by the Swedish pedestrians while the
Jordanians used vague terms like normal or in a hurry, which implies that they were not
concerned about them. They blamed themselves for their involvement in conflicts. The
Swedish pedestrians blamed the drivers. The sub-hypothesis 3-F is verified.

8.2.3 The modification of Swedish TCT -The road-user “pedestrians”
perception of conflict severity

The following analysis is aiming at linking the road-user “pedestrian” perception of
conflict severity assessed from interviews that were made in the two countries with the
proposed modification to the present Swedish TCT. This linking is based on two
perspectives of the road-user perception of conflicts, namely their recognition of conflicts
and rating their severity. It is expected that the road-user “pedestrian” conflict recognition
is higher if the threshold is shifted towards the more severe side of TA-speed graph.

The conflicts that have involved the interviewed pedestrian were grouped according to the
five investigated thresholds (All, GR3, GR4, GR5, and GR6) and based on the three
alternative definitions of RRU concept (Present, high, low). The severity of the recorded
conflicts based on each alternative definition of RRU and threshold was determined. The
proportion of conflicts that were recognised out of all recorded conflicts was calculated for
various thresholds and RRU definitions in each country are presented in Table 8.13.
Table 8.13 Conflict recognition (%) cross tabulated with the tested thresholds for defining conflict severity according to the three investigated definition of conflicts.

<table>
<thead>
<tr>
<th>Severity grade</th>
<th>Conflicts recorded in Sweden</th>
<th>Conflicts recorded in Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present definition of RRU</td>
<td>High definition of RRU</td>
</tr>
<tr>
<td><strong>All recorded</strong></td>
<td>Recognised*</td>
<td>40 41%</td>
</tr>
<tr>
<td></td>
<td>Recorded</td>
<td>98 98%</td>
</tr>
<tr>
<td><strong>Grade 3 or more</strong></td>
<td>Recognised</td>
<td>30 42%</td>
</tr>
<tr>
<td></td>
<td>Recorded</td>
<td>72 90%</td>
</tr>
<tr>
<td><strong>Grade 4 or more</strong></td>
<td>Recognised</td>
<td>24 44%</td>
</tr>
<tr>
<td></td>
<td>Recorded</td>
<td>54 88%</td>
</tr>
<tr>
<td><strong>Grade 5 or more</strong></td>
<td>Recognised</td>
<td>15 47%</td>
</tr>
<tr>
<td></td>
<td>Recorded</td>
<td>32 79%</td>
</tr>
<tr>
<td><strong>Grade 6 or more</strong></td>
<td>Recognised</td>
<td>6 55%</td>
</tr>
<tr>
<td></td>
<td>Recorded</td>
<td>11 46%</td>
</tr>
</tbody>
</table>

*The proportion of recognised conflicts out of all recorded conflicts in each cell is presented in percentages.

Table 8.13 suggests the following:

- The present and the low definition of the RRU provide similar results regarding the proportion of conflict recognition in Jordan for almost all investigated thresholds. On the other hand, the proportion of recognition of conflicts differs in Sweden according to the adopted RRU definition.

- The proportion of conflict recognition in Sweden increases if the threshold is shifted toward the severe side of TA-speed graph. The increase in the recognition is pronounced if either the present or low definition of RRU is used, particularly the low definition, but not if the high definition of RRU is used. The high definition of RRU provides mixed results that do not suggest a clear trend.

- The proportion of conflict recognition in Jordan increases slightly as the threshold is shifted toward the severe side of TA-speed graph. This is applicable if conflicts severity were based on the low and present definitions of RRU.

To conclude, conflict recognition increases as the severity threshold shifted towards the severe side of TA-speed graph. The highest recognition is found to be associated with either the present or the low definition of RRU concept and not the high definition. The low definition of RRU concept performs better for data collected in Sweden. These results are expected because it was the pedestrians that were asked to rate the severity. The low definition of RRU is based on the pedestrian speed and the TA-value (the pedestrian is...
the RRU). Thus, the definition that describes the conflict from the pedestrian perspective is expected to correlate better with the pedestrian recognition of conflicts. To elaborate, the correlation between the interviewed pedestrians’ subjective conflict severity rating and the estimated conflict severity made by the conflict observer is presented in Figure 8.4.

![Figure 8.4](image)

**Figure 8.4** Correlation coefficients that relate the subjective conflict severity rating and the conflict observer conflict rating estimated for various severity thresholds and the three alternative definition of RRU concept.

With some exceptions Figure 8.4 indicates that a positive relationship seems to exist between the interviewed pedestrian subjective severity rating and the estimated conflict observer severity. The higher the subjective severity rating is the higher the conflict observer severity rating, especially for conflicts in Sweden. The estimated correlation coefficients are reported to be higher for the conflict data set collected in Sweden. The low definition performed better than the other two definitions (highest correlation coefficients). The highest correlation coefficient is reported for the present threshold GR5 for conflicts recorded in Sweden, which is intersecting the X-axis of TA-speed graph at 0.5 seconds. For conflicts recorded in Jordan the highest correlation coefficient is reported for severity threshold GR4, which is intersecting the X-axis of TA-speed graph at 0.75 seconds.

The same results were reported when the subjective and objective severity was correlated by considering the severity of 51 conflicts selected out of the 188 conflicts that involved the interviewed pedestrians. Conflict objective severity was determined by using the semi-automatic conflict detection developed at LTH.

To conclude, pedestrians incorporate a scale of severity that correlates with the actual severity of the conflicts. Their assessment of severity is a reflection of what they experience
in traffic; they seem to rate the severity of conflicts based on their own ability of controlling the outcome of the situation. Finally, the low definition of RRU found to be linked to the threshold that was correlated well with their assessment of severity, which are thresholds GR5 and GR4 for Sweden and Jordan respectively. However, it should be clearly stated that it was only the pedestrian perception of conflicts that was investigated. As expected the low definition of RRU produced better results because the severity of conflicts based on the low definition of RRU is determined by considering the pedestrian speed and TA-value.

Conclusions:

♦ Pedestrians in the two countries described their involvement in conflicts differently. Swedish pedestrians tend to use expressions that are related to right of way concept and traffic compliance. Jordanians, on the hand, used terms that depict that they were not paying attention in traffic and they often blame themselves for their involvement in conflicts.

♦ Jordanian pedestrians take evasive action more often than Swedish pedestrians to solve the traffic conflicts they become involved in.

♦ Jordanian pedestrians recognised their involvement in conflicts more than the Swedish.

♦ Swedish pedestrians rate the severity of conflicts they were involved in much lower than Jordanians. However, the selected situations in Jordan were more serious than in Sweden.
8.3 Layman judgement of conflict severity

The Fifty-one conflicts that were selected out of all recorded conflicts that involved the pedestrians that were interviewed in the two countries formed the database for the verification of the following sub-hypotheses:

Sub-Hypothesis (3-G): Road-users from different traffic environments have different perception of conflict severity.

Sub-Hypothesis (3-H): Laymen’s judgement of severity differs from the experts’ judgement due to the influence of traffic environment on their perception of conflict severity.

A wide spectrum of conflict severity was covered while selecting the fifty-one conflicts as shown in Figure 8.5.

Figure 8.5 The severity of the conflicts recorded in Sweden and Jordan that were utilised for evaluating the expert and layman judgements. The present definition of serious conflicts was used in classifying conflict severity.

Three groups of observers were asked to judge the conflict severity subjectively on a scale of one to five points, from now on called “Layman or expert subjective severity rating”. Two groups represented laymen from the two different traffic environments. The last group is formed by experts who were not expected to be influenced by a particular traffic environment. It is envisaged that the layman rating would reflect their general attitude in traffic as traffic users (pedestrians and drivers). In the interview part we were, however, able to investigate the pedestrians’ perception of conflict severity.
8.3.1 Observer reliability tests

Each conflict was viewed four times by each observer. This was to ensure that the reported differences in conflict severity judgement for the selected conflicts are not due to random variation in the judgements, but due to actual differences in their severity. Intra and inter observer reliability were tested by applying the two-tailed correlation coefficient tests to assure that that the observers assessments is reflecting their perception of conflict severity and nothing else (Table 8.14).

**Table 8.14** The intra and inter reliability test results expressed by the mean values of Pearson correlation coefficients for each groups of observers for each country conflict.

<table>
<thead>
<tr>
<th>Country</th>
<th>Trial</th>
<th>Intra-observer reliability</th>
<th>Inter- observer reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Swedish laymen</td>
<td>Jordanian laymen</td>
</tr>
<tr>
<td>Sweden</td>
<td>Trial 2</td>
<td>0.64</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>Trial 3</td>
<td>0.61</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Trial 4</td>
<td>0.57</td>
<td>0.49</td>
</tr>
<tr>
<td>Jordan</td>
<td>Trial 2</td>
<td>0.52</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Trial 3</td>
<td>0.51</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Trial 4</td>
<td>0.40</td>
<td>0.34</td>
</tr>
</tbody>
</table>

The intra-observer subjective severity reliability test measures how consistent each observer is in his or her own severity rating. It was tested by correlating the subjective severity assessment made by each observer at the first trial to the other three assessments. The correlation coefficients of all observers were averaged (Table 8.14). The results indicated that the Swedish laymen are more consistent in their severity assessments than Jordanians, particularly for conflicts recorded in Sweden. The Swedish Laymen are as reliable as experts if they were rating the severity of conflicts in Sweden but not in Jordan. Jordanian laymen are far less reliable than the experts. The experts recorded the highest reliability with relatively small differences in their assessment for conflicts recorded in either Sweden or Jordan.

The inter-observer subjective severity reliability measures how consistent the observers are, within each group, in their judgement of each conflict severity. The subjective severity assessment made by all observers for each conflict at the first trial was correlated with the other three assessments made.

Pearson correlation coefficients that were estimated for each conflict to measure the inter-observer reliability were found to be statistically significant at a 95% significant level for most conflicts that were rated. Only two conflicts from Sweden were found to be associated with insignificant correlation coefficient and they were slight if their severity
was determined based on the present definition of RRU. Despite the fact that the correlation coefficients were significant they were not high. Generally, Jordanian laymen reported the lowest consistency in their assessments of conflicts.

Table 8.14 indicates that the agreement between the Swedish laymen on rating the severity of conflicts recorded in Jordan is similar to the agreement between the Jordanian laymen. It was different though for conflicts recorded in Sweden; the agreement between the Swedish laymen on rating the severity of conflicts is higher than the agreement between Jordanian laymen. The expert group results were rather different from the other two groups. The agreement among expert group on rating the severity conflicts recorded in Sweden was similar to agreement among the layman observers in the other two groups on rating these conflicts. The agreement among observers in the expert group on rating the severity of conflicts recorded in Jordan was higher when compared to their agreements on rating conflicts recorded in Sweden. This may be because the selected conflicts in Jordan were more serious and the experts, who are not supposed to be influenced by a specific traffic environment, are used to detect serious conflicts more than slight conflicts.

Table 8.14 also suggests that intra-observer reliability, with one exception that stands for Jordanian rated conflicts in Jordan, is higher than the inter-observer reliability. This means that each observer is better in producing repeated severity ratings than in producing similar severity ratings as the other observers in the group.

Overall, there is a difference between the laymen groups' reliability as well as between laymen groups and the experts.

8.3.2 Conflict severity rating

The sub-hypothesis to be verified

Sub-Hypothesis (3-G): Road-users from different traffic environments that have a different perception of risk rate conflict severity differently.

The objective severity of each conflict was determined using the semi-automatic technique developed in LTH as basis for verifying the tested hypotheses. The present RRU definition was used to define the conflict severity. The average subjective severity assessed by each observer group for all conflicts that were classified in the same objective severity were determined and correlated to the objective severity (Figure 8.6).
Figure 8.6.1 The average conflict subjective severity rating made by each group of observers for conflicts recorded in Sweden versus the objective severity rating.

Figure 8.6.2 The average conflict subjective severity rating made by each group of observers for conflicts recorded in Jordan versus the objective severity rating.

Figure 8.6 shows that as the objective severity increase the subjective severity increases as well. The same trend was noticeable for the three groups of observers and for conflicts
recorded in each country. Some minor exceptions were reported, particularly, in Sweden, but they were not large so as to influence the overall trend. Pearson correlation coefficients were found to be significant at a 95% confidence level, which was estimated by relating the average subjective severity rating and the objective severity rating for conflicts recorded in Sweden and Jordan, (Table 8.15).

<table>
<thead>
<tr>
<th>Country</th>
<th>Swedish layman</th>
<th>Jordanian layman</th>
<th>Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>0.75</td>
<td>0.87</td>
<td>0.86</td>
</tr>
<tr>
<td>Jordan</td>
<td>0.76</td>
<td>0.95</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Figure 8.6 shows that there were no big differences between the three groups' subjective severity ratings. The Swedish laymen appeared to rate the severity lower than the other two groups. The Jordanian layman severity ratings were rather close to the experts for conflicts recorded in Sweden and were the highest for conflicts recorded in Jordan.

ANOVA tests was used to investigate if there is any differences between subjective severity rating of conflicts that were classified in each objective severity rating due to group type. The test was repeated for each trial and for each country. The results show that there is generally a good agreement between the three groups of observers regarding their judgement on the severity of conflicts that were recorded either in Sweden or Jordan. The highest agreement was reported for conflict severity rating made at the third trial; the observers in the three groups rated the severity of conflicts at each grade of objective severity similarly regardless of the RRU definition used. In general, with very few exceptions there were no significant differences between the Swedish laymen group and the Jordanian layman group. ANOVA test results also showed that there is a good agreement between the layman groups and the expert group. Generally, no significant difference was reported between the three groups of observers.

Therefore, the reported results failed to verify the tested hypotheses. There are similarities rather than differences between the layman assessment of severity, which are not different from the experts’ assessments. It is true that the Swedish laymen rated the severity lower than the other groups but the differences between the three groups were not significant.

**Observers assessment of vehicle speed**

Part of the observation tasks covered the observers' assessment of speed. The observers were asked to estimate the speed of both road-users. They produced a similar estimation of pedestrians speed but not of vehicle speed. The average objective vehicle speed of the selected junction in Sweden was 26 km/h while it was 18 km/h in Jordan. The observers in the three groups overestimated the vehicle speed in Sweden and underestimated it in
Jordan. The Jordanians' assessment was on average higher than the objective speed by 6.1 km/h for conflicts recorded in Sweden, while it was 4.6 km/h for Swedish observers and 2.4 km/h for experts. The experts underestimated the vehicle speed for conflicts recorded in Jordan on average by 2.3 km/h while the Swedish and Jordanian laymen underestimated the objective speed on average by only 0.3 and 0.8 respectively.

8.3.3 Observer subjective rating and the modification of the Swedish TCT

It is expected that the observer would rate the severity of conflicts in a more consistent manner if the conflict severity increased. Serious conflict is accident like and without doubt that these situations would always be considered as serious. However, one should remember that the observers rated the severity from videotapes, which definitely means that they did not experience the conflicts as in real life.

In Table 8.14, the intra-reliability tests were completed by considering all conflicts with various severity for each observer, then the average correlation coefficients for all observers was considered for each group. In the following analysis, the reliability issue is investigated by considering a number of thresholds, but at each group level, no distinction was made for each observer. Conflict subjective severity rating made at the first trial was correlated with second trial for some conflicts that were objectively defined by considering a number of thresholds (Gr3, Gr4, Gr5, Gr6) based on the three alternative definitions of RRU. See Table 8.16.

All estimated correlation coefficients presented in Table 8.16 were proven significant when tested at a 95% significant level. The trend in the results presented in Table 8.16 that refer to conflicts recorded in Sweden shows that shifting the threshold to the severe side of TA-speed graph reported higher correlation coefficients. On the contrary, such a trend is not clear for conflicts recorded in Jordan, particularly for the layman groups.
Table 8.16  The intra-observer reliability evaluated by estimating the correlation coefficient that relates the 1st trial subjective severity of conflict rating to the 2nd trial subjective severity of conflict rating as function of a number of tested thresholds and RRU definitions.

<table>
<thead>
<tr>
<th>RRU Definition</th>
<th>Threshold</th>
<th>Sweden</th>
<th>Jordan</th>
<th>Sweden</th>
<th>Jordan</th>
<th>Sweden</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Swedes</td>
<td>Ukrainians</td>
<td>Expert</td>
<td>Swedes</td>
<td>Ukrainians</td>
<td>Expert</td>
</tr>
<tr>
<td>Present</td>
<td>GR3</td>
<td>0.71</td>
<td>0.67</td>
<td>0.69</td>
<td>0.64</td>
<td>0.64</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>GR4</td>
<td>0.72</td>
<td>0.68</td>
<td>0.70</td>
<td>0.63</td>
<td>0.64</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>0.75</td>
<td>0.68</td>
<td>0.72</td>
<td>0.62</td>
<td>0.62</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>0.73</td>
<td>0.72</td>
<td>0.75</td>
<td>0.60</td>
<td>0.62</td>
<td>0.71</td>
</tr>
<tr>
<td>High</td>
<td>GR3</td>
<td>0.72</td>
<td>0.65</td>
<td>0.72</td>
<td>0.66</td>
<td>0.62</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>GR4</td>
<td>0.72</td>
<td>0.66</td>
<td>0.71</td>
<td>0.66</td>
<td>0.61</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>0.72</td>
<td>0.66</td>
<td>0.73</td>
<td>0.65</td>
<td>0.61</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>0.76</td>
<td>0.70</td>
<td>0.73</td>
<td>0.62</td>
<td>0.64</td>
<td>0.72</td>
</tr>
<tr>
<td>Low</td>
<td>GR3</td>
<td>0.69</td>
<td>0.66</td>
<td>0.67</td>
<td>0.64</td>
<td>0.64</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>GR4</td>
<td>0.70</td>
<td>0.68</td>
<td>0.72</td>
<td>0.67</td>
<td>0.65</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>0.82</td>
<td>0.70</td>
<td>0.77</td>
<td>0.65</td>
<td>0.63</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>0.73</td>
<td>0.79</td>
<td>0.71</td>
<td>0.55</td>
<td>0.56</td>
<td>0.59</td>
</tr>
</tbody>
</table>

The shaded figure refers to the maximum estimated value of correlation coefficients. All correlation coefficients are significant at a 99% significant level.

Although the differences between the calculated correlation coefficients were small, the highest correlation coefficients were reported for thresholds that were based on the low definition of RRU for all groups of observers. The second highest correlation coefficients were reported for thresholds that were based on the present or high definitions of RRU. The threshold that produced the highest correlation differs due to the observer group or country. Threshold GR5 seems to perform well for conflicts recorded in Sweden while it is threshold GR4 in Jordan.

Finally, the objective severity of conflicts was correlated to the subjective severity of conflicts that were estimated by the three groups of observers (Table 8.17). The correlation tests were investigated with respect of the four alternative definition of threshold besides a case that includes all conflicts regardless their severity "All".
Table 8.17  The correlation coefficients between the subjective severity of conflicts made by each group of observers and the objective severity as function of a number of tested thresholds and RRU definitions.

<table>
<thead>
<tr>
<th>RRU Definition</th>
<th>Severity Threshold</th>
<th>Sweden</th>
<th>Jordan</th>
<th>Experts</th>
<th>Sweden</th>
<th>Jordan</th>
<th>Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Swedish layman</td>
<td>Jordanian layman</td>
<td>Experts</td>
<td>Swedish layman</td>
<td>Jordanian layman</td>
<td>Experts</td>
</tr>
<tr>
<td>Present</td>
<td>All</td>
<td>0.30</td>
<td>0.27</td>
<td>0.45</td>
<td>0.21</td>
<td>0.27</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Gr3</td>
<td>0.23</td>
<td>0.13</td>
<td>0.16</td>
<td>0.16</td>
<td>0.23</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Gr4</td>
<td>0.19</td>
<td>0.01</td>
<td>0.17</td>
<td>0.18</td>
<td>0.20</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Gr5</td>
<td>0.20</td>
<td>0.07</td>
<td>0.14</td>
<td>0.14</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Gr6</td>
<td>-0.11</td>
<td>-0.24</td>
<td>-0.12</td>
<td>0.03</td>
<td>0.02</td>
<td>-0.01</td>
</tr>
<tr>
<td>High</td>
<td>Gr3</td>
<td>0.14</td>
<td>0.00</td>
<td>0.13</td>
<td>0.17</td>
<td>0.27</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Gr4</td>
<td>0.04</td>
<td>-0.09</td>
<td>0.09</td>
<td>0.13</td>
<td>0.20</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Gr5</td>
<td>0.02</td>
<td>-0.09</td>
<td>0.07</td>
<td>-0.01</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Gr6</td>
<td>-0.16</td>
<td>-0.27</td>
<td>-0.12</td>
<td>-0.11</td>
<td>-0.06</td>
<td>-0.08</td>
</tr>
<tr>
<td>Low</td>
<td>Gr3</td>
<td>0.36</td>
<td>0.25</td>
<td>0.28</td>
<td>0.19</td>
<td>0.22</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Gr4</td>
<td>0.34</td>
<td>0.16</td>
<td>0.34</td>
<td>0.33</td>
<td>0.27</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Gr5</td>
<td>0.59</td>
<td>0.38</td>
<td>0.42</td>
<td>0.44</td>
<td>0.41</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Gr6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Shaded cell the highest correlation coefficients.
Figures presented in bold style are proved to be significant at a 95% significant level.
1) The cases where no correlation analysis could be made.

The results presented in Table 8.17 indicate that the low definition of RRU produced the highest significant correlation. The results that were reported for the three groups of observers showed that the threshold Gr5 produced the highest value of correlation coefficients. Nevertheless, it is worth remembering that the laymen judgements were completed by observing events from videotapes, where the events would be considered less serious than they might be. The low definition of RRU classifies the conflict severity based on the road-user who is exposed to the least severity; thus conflicts would be less serious than they might be.

Conclusions

- There are no differences in the layman’s assessment of conflict severity due to difference in traffic environment. Layman from Sweden and Jordan rated the severity of conflicts almost the same. Their assessments were not different from the experts, who are believed to be unbiased by a different traffic environment. This implies that laymen judge the conflict severity in a similar manner without being influenced by their traffic environment.
The present definition of serious conflicts (threshold GR5) produced the highest correlation between subjective and objective severity rating, but if only based on the low definition of RRU in classifying the conflict severity.

The overall conclusion concerning the verification of Hypothesis 3 indicated that the road-user's perception of conflict is different in the two countries, although, the results from laymen conflict severity ratings failed to provide significant differences between their perceptions.
9 Conclusions and discussion

This study was aimed at improving the present Swedish TCT with regard to vehicle-pedestrian conflicts at urban junctions. The present definition of conflict severity appears to produce less severe conflicts than they might be, particularly if the relevant road-user (RRU) is the pedestrian.

Equally important was the application of the Swedish TCT in Jordan as a method of evaluating safety conditions at urban junctions. The accident problem in Jordan is more serious than in Sweden. This is due to the differences in road-user behaviour, road infrastructure, the legislation and its enforcement in the two countries.

The influence of the different traffic environments in the two countries on the road-users' perception of conflicts was also investigated. This is expected to provide insight into the safety problem in the two countries.

9.1 Improvement of the present Swedish TCT

The attempts of validating a new definition of conflicts at signalised and non-signalised junctions in Sweden indicated that there is a potential to improve the present definition of conflicts from two perspectives. Firstly, considering an alternative definition of the present RRU definition. Secondly, considering an alternative definition of serious conflicts.

Three approaches for defining conflicts were considered (threshold, severity index and conflict sub-group approach) and three alternative definitions of RRU (present, high, and low) as means of improving the Swedish Traffic conflicts technique (TCT). They produced different results for each type of junction. These results were not in favour of one alternative definition of RRU for both types of junctions or to one common definition of conflicts as shown in Table 9.1.

Table 9.1 A summary of the results of validating various definitions of pedestrian conflicts under each approach of analysis for non-signalised, signalised junctions, and both junction types together in Sweden. (The validity is the better, the smaller the ratio to the best is).

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Present definition</th>
<th>Threshold approach</th>
<th>Severity index approach</th>
<th>Conflict sub-group approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-signalised</td>
<td>GR5 Present 4.22</td>
<td>GR6 Present 2.3</td>
<td>DS41 Low 2.97</td>
<td>V≥20 High Serious 2.48</td>
</tr>
<tr>
<td>Signalised</td>
<td>GR5 Present 33.6</td>
<td>GR6 High 8.64</td>
<td>N321 High 48.8</td>
<td>TA ≤0.75 High All 17.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GR5 High 9.67</td>
<td></td>
<td>V≥30 High Serious 22.02</td>
</tr>
<tr>
<td>All junctions</td>
<td>GR5 Present 4.41</td>
<td>GR6 Present 1.86</td>
<td>N321 High 2.29</td>
<td>TA ≤0.75 High All 1.57</td>
</tr>
<tr>
<td>types together</td>
<td></td>
<td></td>
<td></td>
<td>V≥20 High Serious 3.82</td>
</tr>
</tbody>
</table>
According to Table 9.1 the present definition of serious conflicts in Sweden could be improved by:

- Adopting the high definition of RRU in classifying the conflict severity particularly at signalised junctions.
- Using threshold GR6 that means shifting the present threshold by 0.25 second to the more severe direction of TA-speed graph.
- Using the present threshold GR5 but by excluding all conflicts that have a speed of less than 20km/h at non-signalised junctions and 30km/h at signalised junctions.
- Using only conflicts based on the high definition of RRU which have a time to accident that does not exceed 0.75.

To interpret these results we need to answer the following questions: How do the high, low and present definitions of RRU influence the relationship between conflicts and accidents? What are the implications of shifting the present threshold to the more severe direction of the TA-speed graph? What will we benefit by forming conflict sub-groups?

The relation between relevant road-user definition and conflict severity

Serious conflicts are describing hazardous situations in traffic. They are considered as indicators of a breakdown in the road-users interactions. These are situations involving two or more road users in a collision course that has a high accident potential that makes at least one of the involved road-users act evasively to avoid the accident. If none of the involved road-users acted evasively and an accident happened, then there is probability that this accident will produce injuries. Performing the right type of evasive action is definitely influencing the probability of accident occurrence. Taking a successful evasive action at the right time is a function of the speed of the involved road-users and the TA-value.

The probability of an injury accident, had no road-user acted evasively, is influenced by a number of factors. They include speed of the involved road-users; the road-user’s vulnerability to injury accidents; and the use of safety equipment. In pedestrian conflicts, the speed of the vehicles plays the most important role in defining the probability of injuries. The higher the vehicle speed is the higher the probability of injuries (injury accidents). The vulnerability of the involved road-users is an important factor that influences the probability of injuries. A young man may survive an accident while an elderly woman would not. This study did not look into the vulnerability issue. The influence of the speed on the probability of injury accidents and its relation to the investigated RRU definitions is presented below.

We know there are three basic concepts that define the conflicts in the Swedish TCT. They do not differ according to what RRU definition is used as a basis for classifying the conflict severity. Firstly, a conflict is a situation involving at least two road-users on a collision course. They have their own speeds and distances to the collision point. Secondly, in theory, they should have the same TA-value. Thirdly, both the speed and the
TA-value define the severity of conflicts. Each alternative definition of RRU adopts the value of the speed in a different manner, affecting conflict severity.

For example, the severity of a conflict involving a pedestrian walking at a speed of 5 km/h (1.4 m/sec) and a vehicle at a speed of 35 km/h (9.72 m/sec) with an estimated TA-value of 1.25 seconds would be classified differently according to the RRU definition used. If the present RRU definition is used then the speed and the TA-value of the road-user who made evasive action would determine the severity of conflicts. If the driver acted evasively then the conflict would be classified in severity grade 5 (Figure 9.1). If the pedestrian acted evasively then it would be classified in severity grade 2. If both acted evasively, then the severity would also be classified in grade 2. On the other hand, if the high definition of RRU were used, then it would be classified in severity grade 5. In this case, the driver’s speed controls the severity. If the low definition of RRU were used, then the severity would be classified in grade 2. It is the pedestrian speed that would determine the severity.

![Figure 9.1](image-url)  
*Figure 9.1*  The implication of using the low and high definition of RRU on determining the conflict severity.

According to Figure 9.1, the consequences of classifying conflicts’ severity based on the high definition of RRU would be shifting the conflict severity distribution towards the more severe direction of speed TA-graphs. While the consequences of classifying conflicts’ severity based on the low definition of RRU would be shifting the conflict severity distribution towards the less severe direction of TA-speed graphs. On the other hand, classifying conflicts based on the present definition of RRU might produce conflict distribution that falls in between depending on who takes the evasive action. If the pedestrians take evasive action more often, then the conflict severity distribution would be
shifted towards the less severe direction of the TA-speed graph. On the contrary, if the
drivers do that more often, then the conflict severity distribution would be shifted towards
the more severe direction of the TA-speed graphs.

The results indicated that definitions based on the high definition of RRU produced the
most valid definitions of conflicts for predictions of accidents, particularly at signalised
junctions in Sweden. By considering the high definition of RRU we view the severity of
conflicts according to the vehicles’ speeds and TA-values. If we know the speed of the
vehicle we will be able to judge the severity of an accident if it would have happened.
Conflicts that are involving high-speed vehicles are more likely to produce injury
accidents. Since injury accidents were considered in developing accident to conflict
conversion factors (75) it is expected that classifying conflict severity based on
characteristics (vehicle speed) that depict high probability of injury accidents would
produce better accident predictions. Furthermore, the implication of shifting the conflict
severity to the more severe direction of the TA-speed graph due to high definition of
RRU, would be increasing the number of conflicts in high severity grades (grade 5 or
more). This implies that the variation around the predictions would be smaller than if
fewer conflicts were included when, for example, considering the present definition of
RRU.

Definitions based on the low definition of RRU did not produce as good predictions as
those based on the high definition. By considering the low definition of RRU we view the
severity of conflicts based on the pedestrians’ speeds and TA-values. If we use this
definition we would have no information about the speed of the vehicle and we would not
be able to judge the severity of an accident if it would have happened. Therefore, it is
expected that definitions that do not reflect the possibility of producing injury accidents
are unlikely to have high probability of observing the actual number of accidents. Further,
the implication of shifting the conflict severity distribution towards the less severe
direction of the TA-speed graph will increase the number of conflicts in low severity
grades. Thus, if we base our predictions on the present threshold GR5, only few conflicts
would be classified in severity grade 5 or more. Consequently, the variation around the
prediction would be higher.

The use of the present definition of RRU implies that the speed and the TA-value of the
road-user, who had the ability to take evasive action and still produce the least severity,
would determine the severity of the conflict. The probability of accident occurrence is
highly linked to the possibility of taking evasive action. So, if we base our judgement of
conflict severity on the present definition of RRU we will be able to know what is the
probability of an accident. However, in pedestrian accidents, it is more probable that an
accident would produce injuries. The results indicated that some definitions based on the
present definition of RRU have a high probability of observing the actual number of
accidents. On the other hand, accident predictions based on the present definition of
RRU have high coefficients of variation; particularly those based on threshold GR5 or
GR6 when tested for signalised junctions in Sweden. The number of conflicts classified in
severity grade five or more are less if pedestrians took evasive actions. Accordingly, the
variation around the predictions becomes higher. Nevertheless, the performance of
threshold GR6 at non-signalised junctions produced the smallest coefficient of variation
of the predictions. The recorded conflicts at this type of junctions that are classified in severity grade six or more were serious regardless if the RRU was the driver or the pedestrian. Furthermore, conflicts at non-signalised junctions are characterised by a high speed compared to conflicts at signalised junction. This means that the probability of injuries would be higher if no evasive action were taken at this type of junctions. Thus, conflicts in high severity grades based on the present definition of RRU were sufficient in number to produce high probability of predicting the actual number of accidents for this type of junction (non-signalised).

Threshold approach

Table 9.1 indicated that threshold GR6 produced the most valid definition of conflicts for accident prediction purposes at both non-signalised and signalised junctions. It also produced the second best valid definition when both junction types together were investigated. Shifting the present threshold by 0.25 second towards the more severe side of the speed TA-speed graph (threshold GR6) means that conflicts classified above this threshold are more accident like than some of those that could be classified based on the present threshold, GR5. They are describing situations where the probability of producing injuries is higher.

Thresholds that are intersecting the x-axis of the TA-speed graph at 0.5 seconds or less (GR5, GR6) produced high probability of observing the actual number of accidents, but a higher coefficient of variation of the predictions. One exception was the use of threshold GR6 for accident predictions at non-signalised junctions based on the present definition of the RRU. It produced accident predictions that have a low coefficient of variation and at the same time a high probability of observing the actual number of accidents. Generally, it is expected that this shift would imply the inclusion of fewer conflicts in the analysis. Simple statistics states that the fewer number of observations are, the higher the variation is. On the other hand, these conflicts are characterised by high speed and low TA-values, which provides the possibility of investigating accident like events. Thus, the probability of observing the actual number of accidents increases.

Severity index approach

Some definitions under severity index approach produced good accident predictions similar to those based on the present definition, threshold GR5. Specifically, for predictions made for non-signalised junctions and for all junction types together. Severity indices that describe the conflicts, by considering the events that preceded the conflict and what followed after the evasive action was made, were the most valid tools for accident predictions. However, they did not produce the best predictions, considering their overall ratio to the best in relation to other definitions. Severity indices D541 and N321 were among the valid definitions of conflicts for non-signalised and signalised junctions respectively. They were produced by re-scaling the conflicts according to the following characteristics:
The complexity of situation expressed by

- Possible time available for each road-user to see each other before being involved in the conflict.
- A measure of exposure expressed by either an instant measure of exposure at a distinct time before the conflicts or the change over time in the traffic exposure before the conflicts.

- Vehicle manoeuvre.

- Conflict severity, which is based on the speed and the TA-value of the road-user to the potential accident point.

- The time that separates both road-users after the evasive action was completed.

The process of producing these indices is complicated and it demands collecting information that could not be done on site. Video recording is necessary in order to retrieve the event and collect the necessary information. On the other hand, the performance of the indices as an accident prediction tool was not high enough to justify the required efforts to collect and code the data in order to obtain these indices.

Conflict sub-group

The results indicated that conflict sub-groups \( V \geq 20 \) produced the second lowest overall ratio to the best at non-signalised junctions and \( TA \leq 0.75 \) produced third lowest overall ratio to the best at signalised junctions followed by conflict sub-group \( V \geq 30 \). Conflict sub-group \( TA \leq 0.75 \) produced the best accident predictions when both junction types together were investigated. The high definition of RRU formed the basis for these sub-groups and the present threshold formed the basis for classifying the severity of conflicts for conflict sub-groups \( V \geq 20 \) and \( V \geq 30 \).

Conflict sub-group \( TA \leq 0.75 \) is a modification of the original definition of conflicts in the Swedish TCT. Serious conflicts were originally defined by "A serious conflict occurs when the time to accident (TA) is equal to or less than 1.5 second". The definition was altered in order to be speed dependent since the referred threshold is more applicable in urban areas with a speed limit of 50 km/h (Linderholm, 1981 cited in Linderholm,1992). Nevertheless, the junctions that were included in this study are in urban areas with such a speed limit; the 1.5 seconds threshold could then be a valid threshold for defining the conflict severity.

The modification based on conflict sub-group \( TA \leq 0.75 \) implies shifting the threshold by 0.75 seconds towards the more severe events. To define a serious conflict, the event should have a low TA-value that should not exceed 0.75 seconds (see Figure 9.2).
Figure 9.2  The definition of conflict sub-group $TA \leq 0.75$ and the original definition of serious conflict; $TA \leq 1.5$

The process of defining the severity of conflicts using this modification is not complicated, besides, the technique was originally developed based on the basis of this concept. Hydén’s process validity considered this definition as one alternative that was investigated, although the results were not in favour of it (Hydén, 1987).

Conflict sub-group $V \geq 20$ that was formed by considering serious conflicts based on the present threshold GR5 produced results as good as those reported for threshold GR6 at non-signalised junctions. What does this mean? The performance of the present threshold GR5 can be enhanced by excluding all conflicts where the RRU speed is less than 20 km/h (See Figure 9.3). Conflict sub-group $V \geq 20$ that was considered as a valid tool for accident predictions for non-signalised junctions in Sweden as well as for all junction types together is based on the present threshold GR5 and the high definition of RRU.
Conflict sub-group V ≥ 30, which includes serious conflicts based on the present definition threshold GR5 and the high definition of RRU, produced the highest probability of observing the actual number of accidents for signalised junctions in Sweden. It produced predictions that were close to those produced by conflict sub-group TA ≤ 0.75, the most valid definition for this type of junctions among definitions under conflict sub-group. This shows that for signalised junctions it is not only serious conflicts involving vehicles at a speed less than 20 km/h that should be left out. It is also those with a speed of less than 30 km/h. At signalised junctions in Sweden, more than 90 per cent of the recorded conflicts were involving turning vehicles often characterised by low speeds and thus, low severity grades. These conflicts should be left out from conflicts’ sample that is related to accidents.

Conflict sub-group TA ≤ 0.75 produced the highest probability of observing the actual number of accidents for all junction types together, while conflict sub-group V ≥ 20 produced the smallest coefficient of variation of the predictions. These findings are expected; conflict sub-group TA ≤ 0.75 includes events that are more accident like than some of the situations that are included in conflict sub-group V ≥ 20 (i.e., conflicts with a high TA-value). On the other hand, the inclusion of large number of events, even if some of them are not accident like as in conflict sub-group V ≥ 20, is expected to produce a lower coefficient of variation.
9.2 The application of the Swedish TCT in Jordan

In Jordan, a small number of conflict studies have been carried out, but no Traffic conflicts technique has yet been established. Since the Swedish TCT has been applied in a number of countries including some of the developing countries, it was assumed that it would be applicable in Jordan.

It was expected that since the traffic environments in the two countries are different then definitions that are valid in Sweden are not valid in Jordan. It was also expected that if accident predictions for junctions in Jordan were based on conversion factors developed in Sweden they would not be as good as accident predictions based on conversion factors developed in Jordan.

The results of validating various conflict definitions in Jordan indicated that the most valid conflict definitions in Sweden are not the most valid definitions of conflicts in Jordan, particularly for signalised junctions (Table 9.2).

**Table 9.2** A list of the most valid definitions under each investigated approach for non-signalised and signalised junctions in Jordan as well as all junction types together, including the present definition in the Swedish TCT.
(The validity is the better, the smaller the ratio to the best is)

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Present definition</th>
<th>Threshold approach</th>
<th>Severity index approach</th>
<th>Conflict sub-group approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threshold</td>
<td>RRU</td>
<td>Overall ratio to the best</td>
<td>Threshold</td>
</tr>
<tr>
<td>Non-signalised</td>
<td>GR5</td>
<td>Present</td>
<td>39</td>
<td>GR3</td>
</tr>
<tr>
<td></td>
<td>GR6</td>
<td>Present</td>
<td>41.25</td>
<td></td>
</tr>
<tr>
<td>Signalised</td>
<td>GR5</td>
<td>Present</td>
<td>95</td>
<td>GR3</td>
</tr>
<tr>
<td></td>
<td>GR5</td>
<td>High</td>
<td>72.29</td>
<td></td>
</tr>
<tr>
<td>All junctions</td>
<td>GR5</td>
<td>Present</td>
<td>27</td>
<td>GR6</td>
</tr>
<tr>
<td>types together</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Some of the conflict definitions have high validity for non-signalised junctions in both countries, specifically if based on conflict sub-group approach. For example, conflict sub-group V≥20 has the highest validity for non-signalised junctions in Jordan and has a high validity in Sweden. Threshold GR6 that has relatively high validity among other definitions was also reported to have the highest validity in Sweden. For both junction types together, threshold GR6 was among the most valid definitions in the two countries. Otherwise the valid definitions in the two countries were different.

Table 9.2 indicated that definitions included in conflict sub-group approach were found to be the most valid definitions for non-signalised and signalised junctions. In Sweden
definitions under the threshold approach produced the most valid definitions for non-
signalised and signalised junctions. Classifying conflicts based on the high definition of
RRU was linked to the most valid definitions for each type of junction in Jordan. High
definition of RRU, as said earlier, was also linked to some valid definitions in Sweden,
especially for signalised junctions. The present serious conflicts definition in the Swedish
TCT, including the present RRU definition and the present threshold GR5 did not
produce as good accident predictions as those produced by the most valid definitions of
conflicts shown above.

Data collected in Jordan indicated that a high proportion of recorded conflicts in Jordan
is characterised by vehicles’ low speeds. In addition, pedestrians in 45 per cent of all
recorded conflicts were the RRU based on the present definition. If conflicts’ severity was
classified based on pedestrians’ speed and TA-values, they would not, in general, produce
a high number of conflicts in high severity grades. Thus, predictions based on thresholds
that include few numbers of observations (GR5, GR6) are more likely to have high
variation. On the other hand, classifying the conflicts according to the vehicle’s TA-value
and speed is expected to produce a high number of observations that could produce
accident predictions with small variation. The predictions would be even better if only
serious conflicts determined with the present definition, threshold GR5, with vehicle
speeds of at least 20 or 30km/h were included (conflict sub-group V≥20, or V≥30).

Furthermore, the results indicated that in order to apply the Swedish TCT in Jordan,
there is a need to develop conversion factors especially for Jordan. Predictions made for
signalised junctions and both junction types together in Jordan based on conversion
factors developed for Sweden were not as good as predictions based on conversion factors
developed for Jordan. The results for non-signalised junctions were different according to
the adopted approach in defining the conflict severity. Predictions based on conversion
factors developed in Sweden for some threshold definitions produced poor accident
predictions compared to those based on conversion factors developed in Jordan.
Predictions based on conversion factors that are related to conflict sub-group V≥20,
developed in Sweden, produced reasonable predictions of accidents in Jordan. This might
be attributed to the fact that accident to conflict conversion factors developed in each
country were different in their values, even if the Mann-Whitney test failed to show any
significant differences. Conversion factors in Sweden were higher in their values than the
corresponding factors in Jordan. The differences in the numbers of conflicts and accidents
contribute to the differences in the conversion factors values as well as to those in the
predictions made by utilising these factors. For instance, the recorded numbers of
conflicts were higher in Jordan, but the accident numbers were lower. However, it should
be noted that the accident under-reporting problem, which has not been investigated in
Jordan before, might contribute for the differences in the number of accidents in the two
countries. Conflicts are more serious in Jordan and characterised by close proximity and
small TA-value. Conflict distribution over severity grades is therefore shifted towards the
more severe direction of the TA-speed graph for Jordan. Conflict distribution over
severity grade is shifted towards the less severe direction of the TA-speed graph in Sweden.
Svensson (1998) indicated that the high involvement of road-users in moderately severe conflicts made them learn to avoid the most serious ones, like accidents. The road-users' awareness regarding severe interactions increased due to learning brought by their involvement in less severe interactions. She suggested the present threshold, as a borderline where the involvement of road-users in severe events located just below it would have a learning feedback. Few numbers of accidents were reported at the selected junctions in Jordan and a high number of conflicts, which are classified in severe grades, were also recorded. If investigation shows that accident under-reporting is not high, then it might suggest to reconsider the definition of this borderline in Jordan. It may be that the road-users in Jordan are often involved in situations just slightly above the present threshold of serious conflicts and have learning feedback but not too high risk of accidents. This issue has to be addressed at some later instance.

9.3 Road-user perception of conflicts and their severity

The traffic environments in Sweden and Jordan are different in many aspects including the road-user behaviour, vehicle characteristics, transport infrastructure as well as the legislation and its enforcement. It is anticipated that these differences would influence the road-user perception of the risk involved in conflicts.

Generally, the Swedes either as pedestrians involved in conflicts or as conflict layman observers were found to perceive the conflict severity lower than the Jordanian conflict layman observers. It might be a reflection of their perception that the traffic environment is safe and the situations that they are involved in can be handled safely. They expect that the driver should comply with traffic rules, which makes their expectation even higher. Pedestrians' high expectations at zebra crossings were highlighted by Ekman (1996). He demonstrated that zebra crossings in Sweden are not as safe as they should be because of the pedestrians' high expectations on their right of way, which might be erroneous. It is anticipated that their expectations would be even higher after the new legislation was adopted in May 2000. The vehicle driver in the new legislation is obliged to stop if the pedestrian is about to cross at a zebra crossing. The legislation at the time of performing this study was stating that the driver should adapt his/her speed to avoid placing the pedestrian on the crossing in danger and if necessary he/she should stop. However, this was not the actual driver behaviour. The drivers' speed behaviour at a zebra crossing indicated that the frequency of drivers that gave way to pedestrians was only 5 per cent and only one in four drivers braked in the presence of pedestrians (Várhelyi, 1998).

Jordanian pedestrians as well as Jordanian laymen rated the conflict severity always higher than the Swedish counterparts. It is a reflection of their perception of risk in the traffic environment. They believed that the crossing in traffic is always associated with high risk. They do not expect that the drivers would communicate with them safely. They tend to take evasive actions more often than Swedish pedestrians do.

Based on this it is understandable that the Swedish pedestrian recognition of being involved in conflicts was lower than the Jordanian pedestrian recognition. Most of those who recognised the conflicts in Sweden did not describe their involvement in conflicts as risky situations but as a matter of traffic law compliance. If the drivers complied with the
law, the conflicts would not have occurred in the first place. On the other hand, the
Jordanians were not referring to the right of way problem; yet they recognised the conflict
more frequently and rated their severity higher than the Swedes did. In Jordan, a high
proportion of those involved in conflicts were not paying enough attention in traffic (they
were in a hurry or talking to friends). It might indicate that they are often involved in
conflicts during their normal crossings. They might experience an accessibility problem
that forced them to complete their manoeuvre regardless of the consequences. The low
awareness and enforcement of traffic rules in Jordan was reflected in the pedestrians’
description of conflicts. For instance, the right of way is a vague concept for some of
them. In addition, the enforcement of pedestrians’ right of way is not high enough to
make the pedestrians feel that they have right of way while crossing. It was even more
obvious in their responses when they blamed themselves for being involved in conflicts,
which was not the case in Sweden.

There is a difference in the road-users’ perception of risk of their involvement in conflicts.
This could be a reflection of the differences in the traffic environments. Understanding
the differences in the road-user perception of risk would provide insight into possible
means to influence it. For instance, increasing the level of traffic safety awareness among
Jordanian road-users is needed. Developing the infrastructure to influence the road-user
behaviour is another issue that needs to be highlighted by the relevant authorities.
Enforcing the traffic law is another aspect that should be considered in altering road-user
behaviour. In Sweden, the pedestrian’s high expectation of the safe environment in traffic
is an issue that should be addressed.

9.4 Contributions of this study

This study improves our understanding of the relationship between pedestrian conflicts
and accidents. Alternative definitions for the RRU indicated that our views about the
road-user that should be considered in classifying the conflict severity could be modified.
The definition of conflict concerning how close it is to accidents and how it could be used
reliably in predicting accidents is different from the present definition of serious conflicts.
We are no longer interested in collecting conflicts in low severity grades or conflicts with
low speed and use them for accident prediction purposes.

The use of the high definition of RRU in classifying the conflict severity produced good
accident predictions for signalised and non-signalised junction in the two countries. In
pedestrian conflicts there is a clear distinction between the two road-users’ speed. The
pedestrian has the low speed and the driver the high speed, making the driver as the RRU
according to the high definition. The use of the high definition of RRU might facilitate
the observation of conflicts. The observer can easily assess the vehicle speed and distance
to collision point at any type of junctions or road section and thus define the severity with
good reliability. The observer does not need to estimate the speed and distance of the
pedestrian. This was shown to be problematic. The use of the high definition of RRU as
shown above implies classifying the conflicts in high severity grades. Conflict severity is
determined by considering the vehicle speed. The probability of injuries is related to
vehicle speed, it increases as the vehicle speed increases. Thus, it is interesting to define the
severity of conflicts in a way that reflects such a probability, since injury accidents are more reliably reported than non-injury accidents, including vehicle-vehicle accidents.

The use of threshold GR6 as a borderline for differentiating serious conflicts from non-serious conflicts means that the more we are able to collect conflicts in high severity grades the better are our accident predictions. This means that longer observation periods are needed to collect such type of data. If human observers are used in collecting these conflicts, then it is quite expensive to run conflict studies. Another perspective would be collecting data by objective means like image processing.

The results also indicated that the present definition of serious conflicts in the Swedish TCT (threshold GR5) could be simply improved by excluding conflicts that involve drivers that have a speed less than 20km/h or 30km/h (conflict sub-group \(V \geq 20\) or \(V \geq 30\)). Definition based on conflict sub-group \(V \geq 20\) means that the observers are not any more collecting data about events that would probably not produce injuries in traffic. Conflicts involving road-users (drivers) with low speed might be high in number but they would not reflect a probability of producing injury accidents. The issue of collecting enough data by utilising human observers will be even more resource demanding than collecting data for threshold GR6. This can only be solved by using automated or semi-automated means for data collection.

The results indicated that only some definitions applying severity index approach produced minor improvements to the present definition of serious conflicts. The indices that produced such an improvement demand collecting sophisticated types of information that could not be collected on-site by human observers. The small improvement in validity does not justify the increased efforts in data collection and analysis. The results indicated that simple modifications to the present definition of conflicts produced better improvement to the technique. For example, excluding serious conflicts involving low speed from the present threshold and by considering only the driver speed produced better accident predictions than any other severity indices for non-signalised junctions in Sweden.

The results of applying the Swedish TCT in Jordan showed that the most valid definitions of conflicts were not the same in the two countries. Nevertheless, some definitions were valid in both countries, particularly for non-signalised junctions. In order to apply the technique, it is preferable to develop a definition that takes into consideration the local conditions and establish the corresponding conversion factors. Developing a TCT as a tool that could be used in traffic safety analysis work is of great value in Jordan. It could be used for diagnostic purposes to explore traffic safety problems and for evaluation purposes as well as for accident predictions at similar types of junctions. Its value stems from the fact that collecting accident data at a specific junction in Jordan for diagnostic purposes is not easy. Screening police files is currently the only possible approach to collect the number of accidents. Besides, in a developing country like Jordan continuous developments in the infrastructure are taking place. Thus, evaluating the implementation of new remedial measures based on accident data might be problematic. Many changes could happen in the period that is needed to investigate the possible impact of these measures on safety, based on accident data. This usually requires at least three
years of accident data both before and after the implementation of the measure. Thus, we could not assess the change in safety level as a result of the implementation of the investigated measures solely because many other conditions could have changed at the same time.

9.5 Future research work

A number of potential areas for future research studies were highlighted as a consequence of this study. They include the following:

The results were in favour of the high definition of RRU for pedestrian conflicts. It would be of great interest to investigate the applicability of such a definition for vehicle-vehicle conflicts. If it is applicable, then the second issue that needs to be addressed is “should we modify the definition of serious conflicts for vehicle-vehicle conflicts?” It is anticipated that if vehicle-vehicle conflicts are considered, then defining the road-user based on the high definition of RRU is different. It is not always clear which vehicle has the highest speed, particularly at junctions without any control where the right of way rule applies. The observer needs to collect information about the two vehicles and then define the severity of conflicts based on the vehicle with the highest speed. On priority junctions, the assessment of the vehicle speed and distance to the potential collision point on the priority road would be enough. At roundabouts, the observers are expected to estimate the speed of the approaching vehicle since it has the highest speed.

Definitions included in conflict sub-group approach produced encouraging results for pedestrian conflicts. This might also be applicable for vehicle-vehicle conflicts. However, different criterion for selecting the conflicts that produced the most valid definitions could be used. The criterion that should be used in forming these groups is the relation between the selected conflict characteristics and the probability of injuries. For instance, conflict sub-groups can be formed by considering drivers using a speed of 40km/h or more. It is interesting to investigate if these sub-groups produce better accident predictions than the present definition of conflicts.

For this study, only one conflict characteristic at a time was considered in dividing the conflicts into sub-groups. In future work, these sub-groups could be formed by considering more than one characteristic, for example conflicts involving RRU with a speed of 20km/h or more and interacting with two or more road-users at the junction.

The applicability of the Swedish TCT in Jordan was investigated by considering vehicle-pedestrian conflicts. Vehicle-vehicle conflicts were not part of the study. To be able to develop a comprehensive tool for safety assessment work, there is a need to consider vehicle-vehicle conflicts and develop the related conversion factors. Cycling is not common in Jordan; thus, efforts should not be geared towards establishing conversion factors for motor vehicle-bicycle conflicts as they are rare in Jordan.

The study was in many of its aspects in favour of the high definition of relevant road-user. Svensson (1998) based her work in developing severity hierarchy for three junctions by considering the present definition of conflicts including the RRU definition to define the
event severity in the hierarchy. This study concluded that the threshold definition could be modified as well as the RRU definition. The implication of this on the severity hierarchy for different types of junctions is an interesting issue to be addressed in future research work. In addition, the safety hierarchy can also be investigated by considering conflict sub-groups that produced the most valid definitions (conflict sub-group V≥20 or V≥30).

Pedestrian conflicts were examined in this study for signalised and non-signalised junctions in urban areas. Developing a definition for other types of junctions such as roundabouts or mid-block crossings may be of interest.

More research is needed with respect to the verbal "interview" technique in order to understand the subjective assessment of conflict severity and how this could be related to the objective severity. A limited number of interviews with pedestrians that were involved in conflicts formed the basis for this part of the study. A high proportion of these conflicts in Sweden were non-serious. To be able to learn more on the relationship between the subjective and objective severity, more interviews are needed with road-users involved in conflicts of different severity. The present study, due to practical constraints, covered only the pedestrians' perception of risk embedded in conflicts. The drivers' perspectives were not considered. For future work we need the perspectives of both pedestrians and vehicle drivers. The practical issues might still cause constraints, but eventually these can be solved.

This study did not provide strong evidence that the introduction of severity indices in form of situation specific factors in addition to speed and TA-value could be considered as an enhancement to the present Swedish TCT. It could be because the developed indices were based on subjectively assessed factors. The use of objective factors in defining the severity indices requires collecting large and detailed conflict and accident databases. These databases might facilitate splitting into smaller sub-databases, which have one common factor and perform, for example, discrimination analysis.

Change in road-user behaviour after passing the new legislation in Sweden on the priority of pedestrians over car drivers on zebra crossings and its implication on the safety hierarchy is of interest. Accident to conflict conversion factors at junctions with zebra crossing in Sweden might need modification based on the change of behaviour and its influence on the severity hierarchy. Behaviour studies, including conflict studies, could be made soon to assess the change in behaviour, but we need to wait years before we are able to define the influence of this legislation on the magnitude of the conversion factors.
References


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References


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Appendices
### Table A-1  Name of intersecting streets and their codes and numbers

<table>
<thead>
<tr>
<th>Country</th>
<th>Intersecting streets</th>
<th>Junction code</th>
<th>Junction Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>Regementsgatan - Fersens vägen</td>
<td>RF</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Föreningsgatan - Södra Förstadsgatan</td>
<td>FSF</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Amiralsgatan – Föreningsgatan</td>
<td>AF</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Amiralsgatan – St Knuts vägen</td>
<td>AK</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Drottninggatan – Amiralsgatan</td>
<td>DA</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Östra Förstadsgatan – Drottninggatan</td>
<td>ÖFD</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Hamngatan – Norra Vallgatan</td>
<td>HNV</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Amiralsgatan – Nobelvägen</td>
<td>AN</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Stora Nygatan – Studentgatan</td>
<td>SNS</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Lundvägen – Sallerupsvägen</td>
<td>LS</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Östra Förstadsgatan – Exercisgatan</td>
<td>ÖFE</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Östra Förstadsgatan – Pilgatan</td>
<td>ÖFP</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Stora Nygatan – Malmöborgsgatan</td>
<td>SNM</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Östergatan – Norregatan</td>
<td>ON</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Lilla Nygatan – Studentgatan</td>
<td>LNS</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Östergatan – Mäster Nilsgatan</td>
<td>ÖMN</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Baltrargatan – Djäknegatan</td>
<td>BD</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Östra Tullgatan – Stora Trädgårdsgatan</td>
<td>ÖST</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Stora Nygatan – Engelbrektsgatan</td>
<td>SNE</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Östergatan – Södra Förstadsgatan – Friisgatan</td>
<td>SFF</td>
<td>20</td>
</tr>
<tr>
<td>Jordan</td>
<td>King Fisael Ben Abdel Aziz St.- Al-Rasheed St.</td>
<td>KFR</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Al-Hashmi St.-Al-Sabah St. (Municipality)</td>
<td>HS</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Al-Huson St.- Mou'aueh bin Sofian St.</td>
<td>HMS</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Al-Hasmi St.- Al-Amir Ziad St.</td>
<td>HAZ</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Al-Hashemi St.- M. Khalid Al-Gharebah St.</td>
<td>HKG</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Ali Kholki St.- M. Khalid Al-Gharebah St.</td>
<td>AKG</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Al-Rasheed St.- Ali bin Abu Talib St.</td>
<td>RAT</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Al- Zamanah St.- Ratib-Al Batineh St.</td>
<td>ZRB</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Al-Hashmi St.- Al-Amir Nief St.</td>
<td>HAN</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Omar Al-Mukhtart St.- Al-Radwan St.</td>
<td>OMR</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Abed- Hamid Sharaf St.- Firas Al-Ajuni St.</td>
<td>ASFA</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Palestine St.-Al Rasheed St.</td>
<td>PR</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Al-Hashmi St.- Dalkamon St.</td>
<td>HD</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Abdel-Hami Sharaf St.-Paris Al-Khori St.</td>
<td>ASFK</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Khalid Bin Al St.-Walid- Ain Jalout St.</td>
<td>KWAJ</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Khalid Bin Al St.- Moh'd Bin Sa'eadah St.</td>
<td>KH</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Omar Bin Abdel Aziz St.- Dalkamon St.</td>
<td>OAD</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Al-Karamah St-Dalkamon St.</td>
<td>KD</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Al-Hashemi St.- Husseini St.</td>
<td>HH</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Palestine St.-Abdel-Hamid Sharaf St.</td>
<td>PAS</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>King Hussien St.-Al-Huson St.</td>
<td>KHH</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>King Hussien St.-Omar Bin Abdel Aziz St.</td>
<td>KHOA</td>
<td>42</td>
</tr>
</tbody>
</table>

St.: Street
Figure A-1  A picture of the non-signalised junction in Sweden (Östra Förstadsgatan – Excirsgatan, Junction number 11)

Figure A-2  A picture of a signalised junction in Sweden (Lundavägen – Sallerupsvägen, Junction number 10)
Figure A-3  A picture of a non-signalised junction in Jordan (Al-Hashmi – Al-Almeer Nief, Junction number 29)

Figure A-4  A picture of a signalised junction in Jordan (Al – Hashmi – Dalkamoni, Junction number 33)
### Table A-2

The selected junctions that have special traffic regulations.

<table>
<thead>
<tr>
<th>Country</th>
<th>Junction number</th>
<th>Junction code</th>
<th>Traffic regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>13</td>
<td>SNM</td>
<td>One-way street at Oslg. Kalende approach</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>ÖN</td>
<td>One-way street at the northern approach of Norregatan</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>ÖTST</td>
<td>No entry sign at Stora Trädgårdsgatan northern approach</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>SNE</td>
<td>No entry sign at Engelbrekts gatan approach</td>
</tr>
<tr>
<td>Jordan</td>
<td>21</td>
<td>KFR</td>
<td>No entry sign at King Faisal street eastern approach</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>HAZ</td>
<td>No entry sign at Al-Amir Naif southern approach</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>HKG</td>
<td>No entry sign at M. Gharabah street southern approach</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>HD</td>
<td>No entry sign at Dalkamoni street approach</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>KHS</td>
<td>No entry sign at Ibin Sa’eda street approach</td>
</tr>
<tr>
<td></td>
<td>38</td>
<td>KD</td>
<td>One-way street at Al-Karamah street northern approach</td>
</tr>
<tr>
<td></td>
<td>39</td>
<td>HH</td>
<td>No entry sign at Al-Hussenii street southern approach and one street at Al-Hussenii northern approach</td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>KHH</td>
<td>One-way street at Al-Husun (Al-Aurobah) northern approach</td>
</tr>
</tbody>
</table>
Table A-3
The video camera location and the covered area

<table>
<thead>
<tr>
<th>Country</th>
<th>Junction number</th>
<th>Junction code</th>
<th>Video camera location</th>
<th>Intersection approaches that were covered by the camera’s angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>1</td>
<td>RF</td>
<td>West</td>
<td>The western, eastern, southern and partially northern</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>FSF</td>
<td>West</td>
<td>The western, eastern and partially the southern part</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>AF</td>
<td>South-east</td>
<td>The south-eastern, north eastern and south western</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>AK</td>
<td>South-west</td>
<td>The south-western, north eastern and partially north-eastern</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>DA</td>
<td>South-west</td>
<td>The south-western, and north eastern</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>ÖFD</td>
<td>North-west</td>
<td>The north-western and south eastern</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>HNV</td>
<td>West</td>
<td>The western, eastern and the northern</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>AN</td>
<td>South-east</td>
<td>The south-eastern and north western</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>SNS</td>
<td>South</td>
<td>The southern, northern and western</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>LS</td>
<td>South-east</td>
<td>The south-eastern, north-western and south western</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>ÖFE</td>
<td>West</td>
<td>The western, north-eastern, south-eastern, and partially the southern approach</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>ÖFP</td>
<td>South-east</td>
<td>The south-eastern, north-western, south-western and partially the north-eastern approach</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>SNM</td>
<td>East</td>
<td>The eastern, western, and northern</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>ÖN</td>
<td>East</td>
<td>The eastern, western, and northern</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>LNS</td>
<td>South, and north</td>
<td>The southern, northern, western and partially eastern</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ÖMN</td>
<td>West</td>
<td>The western, eastern and partially northern</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>BD</td>
<td>South</td>
<td>The southern, northern, and western</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>ÖTS</td>
<td>West</td>
<td>The western, eastern and northern</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>SNE</td>
<td>South</td>
<td>The southern, northern, eastern and partially western</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>SFF</td>
<td>South-east</td>
<td>The south-eastern, north-western and partially south-western</td>
</tr>
<tr>
<td>Jordan</td>
<td>21</td>
<td>KFR</td>
<td>South and north</td>
<td>The southern, northern, and western</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>HS</td>
<td>West</td>
<td>The western, eastern, and northern</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>HMS</td>
<td>South and north</td>
<td>The southern, northern, and western</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>HAZ</td>
<td>East</td>
<td>The eastern, western, and northern</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>HKG</td>
<td>East</td>
<td>The eastern, western, and Southern</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>AKG</td>
<td>West</td>
<td>The western, eastern, and southern</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>RAT</td>
<td>North</td>
<td>The northern, southern, and eastern</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>ZRB</td>
<td>North</td>
<td>The northern, southern, and eastern</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>HAN</td>
<td>West</td>
<td>The western, eastern, northern, and partially southern</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>OMR</td>
<td>South</td>
<td>The southern, northern, and western</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>ASFA</td>
<td>South</td>
<td>The southern, northern, and eastern</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>PR</td>
<td>East, west and south</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>HD</td>
<td>East, west and south</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>ASFK</td>
<td>North-west</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>KWAJ</td>
<td>South-west</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>KHS</td>
<td>South-east</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>OAD</td>
<td>East and west</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>38</td>
<td>KD</td>
<td>West</td>
<td>The western, eastern, northern and partially southern</td>
</tr>
<tr>
<td></td>
<td>39</td>
<td>HH</td>
<td>East and west</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>PAS</td>
<td>East</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>KHH</td>
<td>East and west</td>
<td>All approaches</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>KHOA</td>
<td>West</td>
<td>All approaches</td>
</tr>
</tbody>
</table>
Table A-4 The list of junctions in Jordan for which sampling process was adopted to collect conflicts

<table>
<thead>
<tr>
<th>Junction number</th>
<th>Junction code</th>
<th>Car-pedestrian conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>KFR</td>
<td>All serious conflicts and 5 minute sampling of slight conflicts</td>
</tr>
<tr>
<td>23</td>
<td>HMS</td>
<td>All conflicts throughout the recording duration</td>
</tr>
<tr>
<td>24</td>
<td>HAZ</td>
<td>All serious conflicts and 5 minute sampling of slight conflicts</td>
</tr>
<tr>
<td>29</td>
<td>HAN</td>
<td>All conflicts throughout the recording duration</td>
</tr>
<tr>
<td>32</td>
<td>PR</td>
<td>Five minute sampling of serious and slight conflicts</td>
</tr>
<tr>
<td>33</td>
<td>HD</td>
<td>Five minute sampling of serious and slight conflicts</td>
</tr>
<tr>
<td>36</td>
<td>KHS</td>
<td>All serious conflicts and 5 minute sampling of slight conflicts</td>
</tr>
<tr>
<td>41</td>
<td>KHH</td>
<td>All conflicts throughout the recording duration</td>
</tr>
</tbody>
</table>
### CONFLICT RECORDING SHEET

**Observer:**

**Date:**

**Number:**

**Time:**

**City:**

**Weather:**
- Sunny [ ]
- Cloudy [ ]
- Rain [ ]

**Surface:**
- Dry [ ]
- Wet [ ]

**Time Interval:**
- 6:30
- 7:00
- 7:30
- 8:00
- 8:30
- 9:00
- 9:30
- 10:00
- 10:30
- 11:00
- 11:30

**Intersection:**
- North [ ]

<table>
<thead>
<tr>
<th>Road User I</th>
<th>Road User II</th>
<th>Secondary Involved</th>
<th>Description of the causes of event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex M F F F M F F</td>
<td>M F F M F F</td>
<td>Sketch including the position of the road-users involved</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other ( )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The complexity of the situation at the moment that precede the conflict

<table>
<thead>
<tr>
<th>Number of road users in the same group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles</td>
</tr>
<tr>
<td>4 sec. L R O S I R O S I R O S</td>
</tr>
<tr>
<td>3 sec.</td>
</tr>
<tr>
<td>2 sec.</td>
</tr>
<tr>
<td>1 sec.</td>
</tr>
<tr>
<td>Number of pedestrians</td>
</tr>
<tr>
<td>4 sec. L R O S I R O S I R O S</td>
</tr>
<tr>
<td>3 sec.</td>
</tr>
<tr>
<td>2 sec.</td>
</tr>
<tr>
<td>1 sec.</td>
</tr>
</tbody>
</table>

Road user behaviour before the conflict

<table>
<thead>
<tr>
<th>Running/accelerating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Walking/maintaining speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breaking</th>
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<tr>
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</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Stops for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Other (specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Conflict characteristics

<table>
<thead>
<tr>
<th>Speed (km/hr.)</th>
<th>(km/hr.)</th>
<th>(km/hr.)</th>
<th>(km/hr.)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Distance to collision point</th>
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</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T'A value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Type of evasive action

- No action [ ]
- Stopping breaking [ ]
- Changing direction / Swerving [ ]
- Running /acceleration [ ]

The suddenness of the action

- Sudden [ ]
- Not Sudden [ ]

The decisiveness of the action

- Hesitant [ ]
- Decisive [ ]

Controllability of the situation

- Under control [ ]
- Out of control [ ]

Distance to coll. Pt. [ ]

Other information

Errors [ ]

Continued on the other side [ ]
Interview Sheet

County: _______________  Date: _______________
City: _______________  Time: _______________
Video timing: __________

This questionnaire is aiming at explaining road user experience of hazardous situations while passing through intersections; you are kindly requested to answer this questionnaire:

1. Type of road-user
   - □ Pedestrian
   - □ Cyclist
   - □ Driver

2. Sex:
   - □ Female
   - □ Male

3. Age: _______________ year.

4. Have you experienced something unusual in traffic while passing through the pervious intersection?
   - □ Yes
   - □ No

   If the answer to (4) is yes, please continue the questionnaire, otherwise you are thank you for your co-operation.

5. Can you describe what has happened?

________________________________________________________________________

6. How serious do you think the situation was?
   Please mark your answer below.

   No risk of accident at all

   1  2  3  4  5

   Accident

7. Were other road-users involved in the situation?
   - □ Yes
   - □ No

   What kind of road user was involved?
   - □ Pedestrian
   - □ Cyclist
   - □ Driver

8. When did you notice the other road-user?

________________________________________________________________________

9. How fast were you driving at that time?
   Please mark your answer below.

   Slow  Normal  Fast
10. How fast the other road-user was driving at that time?
   Please mark your answer below.
   
   [ ] 1  [ ] 2  [ ] 3  
   Slow  Normal  Fast

11. Have you tried to avoid the situation?
   Yes □  No □
   If your answer to question (11) is No please go to question (15) otherwise answer questions 12-14.

12. What action have you taken to avoid the situation?
   □ Braking  □ Swerving  □ Accelerating
   □ Braking & swerving  □ Accelerating & swerving
   □ Horning  □ Any other action specify (__________________)

13. How abrupt your action was?
   □ Normal  □ Sudden

14. Have you noticed if the other road user has done anything to avoid the situation?
   □ Yes  □ No
   If your answer to question (14) is No please go to question (17) otherwise proceed answer questions 15-16.

15. What action has the other road-user taken to avoid the situation?
   □ Braking  □ Swerving  □ Accelerating
   □ Braking & swerving  □ Accelerating & swerving
   □ Horning  □ Any other action specify (__________________)

16. How abrupt that action was?
   □ Normal  □ Sudden

17. In your opinion, who triggered the incident and how?

18. Were you frightened by the incident?
   Please mark your answer below.
   
   [ ] 1  [ ] 2  [ ] 3  [ ] 4  [ ] 5  
   Not at all  Shocked & terrified

Thank you for your patience, and we hope you have a safe Journey.
## Laymen-expert observation sheet: Step 1

<table>
<thead>
<tr>
<th>No</th>
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<th>Severity Grade</th>
<th>Probability of injury accident</th>
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<td>1 2 3 4 5</td>
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<td>Blue pickup; Two men. One soldier, and the other civilian.</td>
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<td>Golden brown Honda; Young man in a light shirt.</td>
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## Laymen-expert observation sheet: Step 2

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<td>1 2 3 4 5</td>
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<td>Bus; Tall man with blue cap, red jacket and two plastic bags.*</td>
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<td>White light vehicle; Two young men. One in white shirt, one in black.</td>
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<td>Red car; Two women.</td>
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<td>Bus: Tall man with blue cap, red jacket and two plastic bags.*</td>
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<td>White van; Woman with a bag.</td>
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<td>Small white van; Old lady in black traditional clothes.</td>
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<td>Dark Volvo; Almost bold man wearing a green jacket.</td>
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<td>Grey car; Woman with dark-brown skin-jacket. Smokes.</td>
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<td>Dark American car; Long-haired woman with a bag.</td>
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### Layman-expert observation sheet: Step 4

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<td>Blue pickup: Two men. One soldier, and the other civilian.</td>
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<td>Turning white taxi: Older couple with light clothes.</td>
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<td>Green Mercedes: Man in blue shirt.</td>
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<td>White Saab: Dark-haired boy with a bicycle.</td>
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<td>Bus: Woman with blue jacket, visor hat and a bag.</td>
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<td>White Saab: Tall man with a cap. Had to run temporarily.</td>
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### Table C-1: Distribution of car-pedestrian registered conflict severity at the selected intersections

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</table>

W: West  N: North  E: East  S: South
### Table D-1  Coefficients used in estimating the conflict severity index

<table>
<thead>
<tr>
<th>Severity grade</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7 or ore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\alpha$</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
<td>0.7</td>
<td>0.7</td>
<td>1.0</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conflict category “Turning conditions”</th>
<th>Turning</th>
<th>Not-turning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\beta$</td>
<td>1.25</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time separating road-users after the completion of evasive action (sec)</th>
<th>$&lt;0.5$</th>
<th>$0.5\leq x&lt;0.75$</th>
<th>$0.75\leq x&lt;1.0$</th>
<th>$1.0\leq x&lt;1.25$</th>
<th>$1.25\leq x&lt;1.5$</th>
<th>$1.5\leq x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\delta$</td>
<td>1.25</td>
<td>1.0</td>
<td>1.0</td>
<td>0.9</td>
<td>0.9</td>
<td>0.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Available time to see each other code</th>
<th>$1\leq x$</th>
<th>$1&lt; x\leq2$</th>
<th>$2&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\gamma$</td>
<td>1.5</td>
<td>1.0</td>
<td>0.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Passenger car</th>
<th>Other vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\psi$</td>
<td>0.9</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instant number of traffic streams exposure index (TSN, TSN)</th>
<th>$x\leq0$</th>
<th>$0&lt; x\leq1$</th>
<th>$1&lt; x\leq2$</th>
<th>$2&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\phi_4-\phi_1$</td>
<td>0.75</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difference in number of traffic streams exposure indices $D(TSN, -TSN)$, $x$ varies from 4 to 2</th>
<th>$x&lt;0$</th>
<th>$x=0$</th>
<th>$0&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\phi_{41}-\phi_{21}$</td>
<td>1.15</td>
<td>1.0</td>
<td>0.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instant traffic stream summation exposure index (TSS, TSS)</th>
<th>$0&lt; x\leq1$</th>
<th>$1&lt; x\leq2$</th>
<th>$2&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\lambda_4-\lambda_1$</td>
<td>0.75</td>
<td>1.0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difference in the instant traffic stream summation exposure indices $D(TSS, -TSS)$, $x$ varies from 4 to 2</th>
<th>$x\leq2$</th>
<th>$x=-1$</th>
<th>$x=0$</th>
<th>$x=1$</th>
<th>$2&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\eta_{41}-\eta_{21}$</td>
<td>1.2</td>
<td>1.1</td>
<td>1.0</td>
<td>0.9</td>
<td>0.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weighted instant exposure index ($WTS_i - WTS$)</th>
<th>$x\leq0$</th>
<th>$0&lt; x\leq1$</th>
<th>$1&lt; x\leq2$</th>
<th>$2&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\omega_{41}-\omega_{21}$</td>
<td>1.5</td>
<td>1.2</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difference in the weighted instant exposure index ($WTS_i - WTS$), where $x$ varies from 2 to 4</th>
<th>$x\leq6$</th>
<th>$-6&lt; x&lt; -3$</th>
<th>$x=0$</th>
<th>$x=1$</th>
<th>$0&lt; x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient $\rho_{41}-\rho_{21}$</td>
<td>1.3</td>
<td>1.2</td>
<td>1.1</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Table D-2  Weighted instant exposure index formulas

<table>
<thead>
<tr>
<th>Road-user type</th>
<th>Weighted instant exposure index formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle driver</td>
<td>(2(\Sigma CL) + 2(\Sigma CR) + 1.5(\Sigma CSL) + 1.5(\Sigma CSR) + 4(\Sigma CO) + 1(\Sigma CS) + 3(\Sigma B) + 3(\Sigma P))</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>(3(\Sigma C) + \Sigma B - 0.25(\Sigma PO) - 0.5(\Sigma PS))</td>
</tr>
</tbody>
</table>

Where:
- CL: Number of vehicles on the left
- CSL: Number of vehicles on the same direction on the left side
- CR: Number of vehicles on the right
- CSR: Number of vehicles on the same direction on the right side
- CO: Number of vehicles on the opposite direction
- CS: Number of vehicles on the same direction
- B: Number of bicycles at the intersection that might influence the involved road-user decision
- P: Number of pedestrians at the intersection that might influence the involved road-user decision
- C: Number of vehicles at the intersection that might influence the involved road-user decision
- PO: Number of pedestrians on the opposite direction
- PS: Number of pedestrians on the same direction
<table>
<thead>
<tr>
<th>Severity index</th>
<th>Conflict characteristics that constitute the index</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Conflict severity grade.</td>
</tr>
<tr>
<td>SC</td>
<td>Conflict severity grade - conflict category.</td>
</tr>
<tr>
<td>SCT</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action.</td>
</tr>
<tr>
<td>SCTA</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts.</td>
</tr>
<tr>
<td>SCTAV</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type.</td>
</tr>
<tr>
<td>N4</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type - The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at four seconds before conflict.</td>
</tr>
<tr>
<td>N43</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type - The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at four seconds before conflict- The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at three seconds before conflict.</td>
</tr>
<tr>
<td>N432</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type - The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at four seconds before conflict- The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at three seconds before conflict- The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at two seconds before conflict.</td>
</tr>
<tr>
<td>N4321</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type - The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at four seconds before conflict- The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at two seconds before conflict- The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at one seconds before conflict.</td>
</tr>
<tr>
<td>N3</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type - The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at three seconds before conflict.</td>
</tr>
<tr>
<td>N32</td>
<td>Conflict severity grade - conflict category-distance to collision after the completion of the evasive action- the possible available time for the road-users to see each other before the conflicts-vehicle type - The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at three seconds before conflict- The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at two seconds before conflict.</td>
</tr>
<tr>
<td>Severity index</td>
<td>Conflict characteristics that constitute the index</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>N321</td>
<td>Conflict severity grade - conflict category: distance to collision after the completion of the evasive action. The possible available time for the road-users to see each other before the conflict - vehicle type The sum of the numbers of traffic streams were there were road-users in at the scene, which might directly interact, or might influence his behaviour, measured at three seconds before conflict.</td>
</tr>
</tbody>
</table>
## Table D-3  Severity index Definitions

<table>
<thead>
<tr>
<th>Severity index</th>
<th>Conflict characteristics that constitute the index</th>
</tr>
</thead>
<tbody>
<tr>
<td>S432</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at four seconds before the conflict - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at three seconds before the conflict.</td>
</tr>
<tr>
<td>S4321</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at four seconds before the conflict - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at three seconds before the conflict.</td>
</tr>
<tr>
<td>S3</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at three seconds before the conflict.</td>
</tr>
<tr>
<td>S32</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at three seconds before the conflict.</td>
</tr>
<tr>
<td>S321</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at three seconds before the conflict.</td>
</tr>
<tr>
<td>S2</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at two seconds before the conflict.</td>
</tr>
<tr>
<td>S21</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at two seconds before the conflict.</td>
</tr>
<tr>
<td>S1</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - The sum of all road-users that happened to be at the scene, which might directly interact, or might influence his behaviour measured at one second before the conflict.</td>
</tr>
<tr>
<td>Severity index</td>
<td>Conflict characteristics that constitute the index</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>DS41</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - Difference between the sum of the road-users that were happened to be at the junction measured at four and at one second before conflict.</td>
</tr>
<tr>
<td>DS31</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - Difference between the sum of the road-users that were happened to be at the junction measured at three and at one second before conflict.</td>
</tr>
<tr>
<td>DS21</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - Difference between the sum of the road-users that were happened to be at the junction measured at two and at one second before conflict.</td>
</tr>
<tr>
<td>W4</td>
<td>Conflict severity grade - conflict category - distance to collision - available time - road-user type - weighted exposure index calculated at four seconds before conflict - weighted exposure index calculated at three seconds before conflict.</td>
</tr>
<tr>
<td>W43</td>
<td>Conflict severity grade - conflict category - distance to collision - available time - road-user type - weighted exposure index calculated at four seconds before conflict - weighted exposure index calculated at three seconds before conflict.</td>
</tr>
<tr>
<td>W432</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at four seconds before conflict - weighted exposure index calculated at three seconds before conflict.</td>
</tr>
<tr>
<td>W4321</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at four seconds before conflict - weighted exposure index calculated at three seconds before conflict - weighted exposure index calculated at one second before conflict.</td>
</tr>
<tr>
<td>W3</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at three seconds before conflict.</td>
</tr>
<tr>
<td>W32</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at three seconds before conflict - weighted exposure index calculated at two seconds before conflict.</td>
</tr>
<tr>
<td>W321</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at three seconds before conflict - weighted exposure index calculated at two seconds before conflict.</td>
</tr>
<tr>
<td>W2</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at two seconds before conflict.</td>
</tr>
<tr>
<td>W21</td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at one seconds before conflict.</td>
</tr>
</tbody>
</table>
### Table D-3  Severity index Definitions

<table>
<thead>
<tr>
<th>Severity index</th>
<th>Conflict characteristics that constitute the index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>W1</strong></td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - weighted exposure index calculated at one second before conflict.</td>
</tr>
<tr>
<td><strong>DW41</strong></td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - Difference between the weighted instant exposure index calculated at four seconds and at one second before conflict.</td>
</tr>
<tr>
<td><strong>DW31</strong></td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - Difference between the weighted instant exposure index calculated at three seconds and at one second before conflict.</td>
</tr>
<tr>
<td><strong>DW21</strong></td>
<td>Conflict severity grade - conflict category - distance to collision after the completion of the evasive action - the possible available time for the road-users to see each other before the conflicts - vehicle type - Difference between the weighted instant exposure index calculated at two seconds and at one second before conflict.</td>
</tr>
</tbody>
</table>