Road Safety Modeling Using a Safety Analysis Chain: A Theoretical Discussion

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- Research Background
- Safety Analysis Chain (SACH)
- Quantifying Components of the SACH
- Future Research
- Conclusion
## Research Background

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<td>Experiments and Studies to Understand Human Behaviour</td>
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</table>
Safety Analysis Chain (SACH)

- Exposure
- Crash risk per exposure
- Kinetic energy per crash
- Transfer of kinetic energy to pedestrian
- Human tolerance

KEM (Corben et al., 2004)
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Safety Analysis Chain (SACH)

Exposure | Crash Risk Per Exposure | Kinetic Energy Per Crash

TRAFFIC FLOW → CONFLICT → SEVERE CONFLICT → CRASH → SEVERE CRASH

Exposure

Crash Risk Per Exposure

Kinetic Energy Per Crash

Institute of Transport Studies

MONASH University
SACH (Link of Events)

TRAFFIC
- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

CONFLICT
- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

SEVERE CONFLICT
- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

CRASH
- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

SEVERE CRASH
- Human Characteristics
- Road Characteristics
- Vehicle Characteristics
SACH(Variables)

- **TRAFFIC**
  - Road Layout
  - Flow
  - Density
  - Speed
  - Headway
  - Control Char.

- **CONFLICT**
  - Conflict Type
  - Vehicles Involved
  - Maneuvers
  - Speed Before Conflict
  - Acceleration/Dec
  - Vehicles Position

- **SEVERE CONFLICT**
  - Conflict Type
  - Vehicles Involved
  - Maneuvers
  - Speed
  - Acceleration/Dec
  - Position

- **CRASH**
  - Crash Type
  - Vehicles Involved
  - Impact Angle
  - Speed Before Crash
  - Impact Type
  - Impact Location

- **SEVERE CRASH**
  - Crash Severity
  - Abbreviated Injury Scale (AIS)
  - Injury Severity Score (ISS)
  - Kinetic Energy
  - Delta V
  - EBS
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Researchers have developed several conflict techniques to find out the number and severity of conflicts using micro-simulation model (Hyden 1987; Hyden 1996; Archer 2005).

After generating individual vehicle movement, the conflicts could be determined using probabilistic human behaviour models such as lane changing, car following, gap acceptance and stop-or-go decision at the onset of amber (Archer 2005; Cunto and Saccomanno 2008; Archer and Young 2009).
Quantifying Components of the SACH (Step 2)

Step 1: Modelling The Link Between “Traffic” and “Conflict” and “Severe Conflict”

Step 2: Modelling The Link Between “Crash” and “Severe Crash”
Quantifying Components of the SACH (Step 2)

- Crash Type
- Vehicles Involved
- Impact Angle
- Speed Before Crash
- Impact Type
- Impact Location

TRAFFIC

CONFLICT

SEVERE CONFLICT

CRASH

SEVERE CRASH

- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

- Human Characteristics
- Road Characteristics
- Vehicle Characteristics
Quantifying Components of the SACH (Step 2)

CRASH POTENTIAL ENERGY → Kinetic Energy of Vehicles (Pre-Crash)

CRASH CHARACTERISTICS

CRASH SEVERITY → KE_s ∝ f_1 (Crash Characteristics) (1)

IMPACT / OCCUPANT CHARACTERISTICS

INJURY SEVERITY → ISS ∝ f_2 (Impact Characteristics, Occupant Characteristics, and KE_s) (2)

(1) f_1 is the mathematical model presenting the kinetic energy transferred to the subject vehicle in crash according to crash characteristics.

(2) f_2 is the mathematical model presenting the ISS of the crash according to impact characteristics, kinetic energy transferred to the subject vehicle, and occupant characteristics.
Quantifying Components of the SACH (Step 2)

\[ 
\Delta V_s = v^b_s - v^a_s = \frac{m_a}{m_b} \left[ v^a_b (\cos \alpha^b_a + \frac{\sin \alpha^b_a}{\sin \alpha^a_s \tan \alpha^a_s}) - v^b_s \left( \frac{\sin (PDOF)}{\sin \alpha^a_s} + \cos (PDOF) - \frac{\sin (PDOF)}{\tan \alpha^a_s} \right) \right] 
\]
Quantifying Components of the SACH (Step 3)

**Step 1:** Modelling The Link Between “Traffic” and “Conflict” and “Severe Conflict”

**Step 2:** Modelling The Link Between “Crash” and “Severe Crash”

**Step 3:** Modelling The Link Between “Severe Conflict” and “Crash”
Quantifying Components of the SACH (Step 3)

- Characteristics of Conflicts
- Characteristics of Crash
- Injury Severity Score
Quantifying Components of the SACH (Step 3)

Levels of Driver Behaviour Modelling

Tactical Level | Control Level | Control Level

Traffic Flow → Conflict → Severe Conflict → Crash → Severe Crash
Quantifying Components of the SACH (Step 3)

Step 1: Modelling The Link Between “Traffic” and “Conflict” and “Severe Conflict”

Step 2: Modelling The Link Between “Crash” and “Severe Crash”

Step 3: Using an Alternative Model
Quantifying Components of the SACH (Step 3)
Quantifying SACH (Step 3)

TRAFFIC FLOW → CONFLICTS → SEVERE CONFLICTS → CRASHES → SEVERE CRASHES

CONFLICTS

CONFLICT CHARACTERISTICS, DRIVER REACTION IN CONFLICT

EXPECTED KINETIC ENERGY

EXPECTED IMPACT CHARACTERISTICS

EXPECTED INJURY SEVERITY

Vehicles Involved In a Conflict

$KE_s \cdot f_1$ (Conflict Characteristics, Driver Reaction in Conflict)

ISS $f_2$ (Expected Impact Characteristics, and $KE_s$)
Quantifying Components of the SACH (Step 3)

\[ KE_s = \frac{1}{2} \times m \times \Delta V_s^2 \]

\[ KE_s = \frac{1}{2} \times m_s \times \left[f_3(\text{CC}, \text{DR})\right]^2 \]
Quantifying Components of the SACH (Step 4)

**Step 1:** Modelling The Link Between “Traffic” and “Conflict” and “Severe Conflict”

**Step 2:** Modelling The Link Between “Crash” and “Severe Crash”

**Step 3:** Using an Alternative Model

**Step 4:** Road Safety Index
Quantifying Components of the SACH (Step 4)

COMPONENT 1: Micro-Simulation Model
OUTPUTS:
• Number of Conflicts
• Severity of Conflicts
• Characteristics of Conflicts

INPUT: Road, Environment and Traffic Characteristics

COMPONENT 2: Severity Model (Three Models)
Driver Reaction Model
OUTPUT:
• Driver Reaction Before Crash
ΔV Model
OUTPUT:
• ΔV
• Kinetic Energy
ISS Model
OUTPUT:
• Injury Severity Score

COMPONENT 3: Average Number of Crashes
OUTPUT:
• Average Number of Crashes

Road Safety Index
Road Safety Index

\[ RSI = \left[ \left( \sum_{i=1}^{n_{con}} ISS \right) / n_{con} \right] \times n_{cr} / \mu \]
## DATA

<table>
<thead>
<tr>
<th>Model</th>
<th>Calibration</th>
<th>Validation/Verification</th>
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<tbody>
<tr>
<td>Micro-Simulation Model</td>
<td>SCATS data</td>
<td>SCATS data</td>
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<td>Recorded Video</td>
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<td>Police Data</td>
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<td>Driver Reaction Model</td>
<td>ANCIS Database</td>
<td>ANCIS Database</td>
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<tr>
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<td>NASS Database</td>
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<tr>
<td>∆V Model</td>
<td>ANCIS Database</td>
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<td>ISS Model</td>
<td>ANCIS Database</td>
<td>ANCIS Database</td>
</tr>
<tr>
<td></td>
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<td>NASS Database</td>
</tr>
</tbody>
</table>
Future Research

- Road Layout
- Flow
- Density
- Speed
- Headway
- Control Char.

- Conflict Type
- Vehicles Involved
- Maneuvers
- Speed Before Conflict
- Acceleration/Dec
- Vehicles Position

- Crash Type
- Vehicles Involved
- Impact Angle
- Speed Before Crash
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- Impact Location

- Crash Severity
- Abbreviated Injury Scale (AIS)
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TRAFFIC → CONFLICT → SEVERE CONFLICT → CRASH → SEVERE CRASH

- Human Characteristics
- Road Characteristics
- Vehicle Characteristics

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Conclusion

- A Safety Analysis Chain (SACH) has been introduced as a basis for assessing safety performance of roads.

- A method has been outlined to quantify the components of the SACH through integrating the preceding safety modelling perspectives.

- The proposed theoretical framework proposed takes an important step towards the evaluation of the safety performance of roads.

- The SACH framework is a key for future research in road safety modelling since it provides a general overview of the main components of road safety modelling.
Questions
Quantifying Components of the SACH (Step 3)