Freeway Integrated Incident Management System

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Contents

1. Backgrounds
2. Traffic Characteristics
3. Incident Detection (ID)
4. Estimation of Incident Probability (EIP)
5. Integrated Incident Management (IIM)
Backgrounds

- **Intelligent Transportation Systems Master Plan**
  - Preliminary ITS Plan (1994)
  - Transportation Efficiency Act (1999)
  - ITS Master Plan (1999, currently under revision)

- **Intelligent Transportation Systems Research and Development Program**
  - Develop Key System Elements for ITS
  - System Integration
  - Efficiency and Productivity

- **ITS Model Deployment Program**
  - Kwachon (1996) : ITS World Congress Demonstration Site
## Research Scope

<table>
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<th><strong>Existing Research Review</strong></th>
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<td><strong>Analysis of Traffic Characteristics</strong></td>
<td>- Study Area</td>
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<td>- Traffic Characteristics under Incident</td>
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<td>- Simulation Analysis</td>
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<td><strong>Evaluation of Incident Detection Algorithms</strong></td>
<td>- Develop Testing Scenarios</td>
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<td>- Categorize Incident Type and Traffic Situation</td>
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<td>- Develop Evaluation Software</td>
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<td>- AIP, DELOS, DES, McMaster</td>
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<td><strong>Development of Estimation of Incident Probability and Response Scheme</strong></td>
<td>- Estimation of Incident Probability (EIP)</td>
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<td>- Modeling for Incident Duration</td>
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<td>- Integrated Incident Management Program Modules</td>
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Incident Components

- **Incident Detection (ID)**: automatic/manual detection
- **Incident Verification (IV)**: Severity, Duration, Impact
- **Incident Response (IR)**: IRT, Information Dissemination
- **Incident Clearance (IC)**: Technology and Methods
Integrated Incident Management

- ID, IR, IC
- Estimation of Incident Probability
- Incident Information Management (IIM): DB and ADUS
- Frequent Construction Work
- Accidents are major cause for 5km more Delay
Traffic Impact

Year 2000 – Year 2002

Incident Duration

<table>
<thead>
<tr>
<th>Duration</th>
<th>Count</th>
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<tbody>
<tr>
<td>Normal</td>
<td>5946</td>
</tr>
<tr>
<td>10 min &lt;</td>
<td>758</td>
</tr>
<tr>
<td>10-30 min</td>
<td>2811</td>
</tr>
<tr>
<td>1 hrs</td>
<td>1391</td>
</tr>
<tr>
<td>1-5 hrs</td>
<td>584</td>
</tr>
<tr>
<td>5-10 hrs</td>
<td>758</td>
</tr>
<tr>
<td>&gt;10</td>
<td>0</td>
</tr>
</tbody>
</table>
Data Collection

1. Detector Type
   • Space continuity: good detector data for analysis area
   • Time Continuity: Time-Series Data

2. Traffic Environments
   • IC/JC Type
   • Traffic Volume
   • Environmental and Geometric Elements

3. Type of Incident
   • Degree of Congestion
   • Continuous Data for Entire Incident Duration
   • Isolate the Incident
Smoothing with Moving Average Method

Raw Data

![Raw Data Graph]

After Smoothing Process

![After Smoothing Graph]
Traffic Characteristics

- Normal Flow Vs. Incident Flow
- Lane Grouping (All lane Flow Vs. Individual lane flow)
- Traffic Flow Analysis before/after Incidents
  - Time-series Analysis
  - Reference Points Analysis
- Traffic Flow Analysis with Detection Type
  - loop, Video Imaging, magnetic
- Traffic Flow Analysis with Different Aggregation Interval
  - 30sec, 2min, 5min
Normal Flow Vs. Incident Flow

- **Normal Flow**
  - Breakdown at capacity
  - Transition Stage

- **Incident Flow**
  - Non-linear at Capacity
  - Traffic Break down from the Incidents
Lane Grouping

- **Speed Variation**
  - Individual Lane Analysis
    - Abrupt Speed Change (80km/h to 20km/hr)
  - Combined Lane Analysis
    - Maintain higher speed (60km/hr)
    - Average effect

- Using Individual Lane Data for Automatic Incident Detection
Space-series Traffic Analysis

Incident Location (317.0 km)
time-speed diagram

incident starts at 16:15
incident duration: 35min (16:50)
queue dissipation: 3hrs 15min (20:05)
Traffic Characteristics by Location

Volume-Occupancy

Volume (Veh/5 min)

Occupancy (%)

307.3km
308.4km
316.1km

320.7km
320.0km
317.0km

교통량-점유율 관계

교통량(대/5분)

점유율(%)
Traffic Characteristics by Detector type

- Different Volume-Occupancy Shape
- Critical Occupancy
  - Loop (15%)
  - Video (20%)
  - Magnetic (10%)

Using Different Parameter by Detector Type
Aggregation Interval

- Difficult to identify with short aggregation interval (stable to unstable)

- Big occupancy difference for short aggregation interval

Polling Cycle
Time to Detection

- 30sec
- 2min
- 5min
Traffic Simulation

- **Model Selection**
  - Microscopic Simulation Package
  - Virtual Traffic Environment
  - Paramics
  - 37 scenarios
  - 30sec time interval
Validation Process

- Real data
- Speed Variation
- Flow-Occupancy
Occupancy and Speed

Raw Data from Detector

Occupancy

Time

Speed (km)

Time (시 : 분 : 초 )
Detection Time by Algorithm

API D detection time: 18:45:30
DES detection time: 18:46:30
DELOS detection time: 18:46:31

Traffic volume, occupancy rate, speed

Incident history data (19:01 - 20:16)

Sensor location (19:01 - 20:16)
Incident Detection Algorithm MOE

- Mean Detection Time and False Alarm Rate: APID
- Detection Rate and Time to Detect: McMaster
- Detection Rate: DELOS
  - APID: Type 0, 1
  - DES: Type 1
  - DELOS: Type 2
Incident Detection Algorithm

- **APID, DES, DELOS**
  - Heuristic Parameter Search
    - Not related with historical data
    - High sensitivity – Difficult to find optimum parameters
  - APID: Need two continuous detector data
    - Not good for IC and JC
  - DES: Long detection time, low detection rate
    - High Sensitivity
    - Depend on occupancy data
  - DELOS: Long detection time caused by smoothing
Incident Detection Algorithm

- McMater
  - Parameter estimation by historical data
  - Parameter estimation by detector type and lane group
  - Can use various detector data
    -1, 0 +1 at least three detectors
  - At least one week data needed
Development Direction

- Average Data ➔ Individual Data
- Different Parameter for detector type
- Automatic parameter generation by traffic characteristics
- Need different parameter near IC, JC and Weaving Area
- Using several different aggregation interval
- Decision Matrix using DELOS and McMaster
- Garbage In, Garbage Out
Incident Prevention

- Patrol
- Optimum resource management
- Historical data analysis:
  - time, route, location, incident type, weather etc.

![Time-Space Incident Analysis Graph](image-url)
Estimation of Incident Probability

- Statistical Analysis using geometric, weather and traffic characteristics
- Using decision support system to determine problem area for special surveillance and management

Model Definition
Variables Selection

Parameter Estimation
Estimation

Critical Value
Optimum Value

Feedback
Estimation of Incident Probability

LOGIT Model

- SPEEDVOL: Volume weighted average speed
- SCHOM_VC: Average volume/capacity ratio
- D1_D2: Density Difference(lane1, lane2)
- V1_V2: Volume difference (lane1, lane2)

\[
P_i = \frac{\sum_{j=0}^{m_i} \exp(x_{ij} \beta)}{\sum_{j=0}^{m_i} \exp(x_{ij} \beta) + \exp(x_{ij} \beta)},
\]

\[i = 1, 2, \ldots, n \quad \text{and} \quad j = 0, 1, \ldots, m_i\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficients</th>
<th>standard error</th>
<th>Coeff./S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEEDVOL</td>
<td>-0.03046</td>
<td>0.00545</td>
<td>-5.58987</td>
</tr>
<tr>
<td>SCHOM_VC</td>
<td>-14.92854</td>
<td>2.72016</td>
<td>-5.48810</td>
</tr>
<tr>
<td>D1_D2</td>
<td>-0.02024</td>
<td>0.00939</td>
<td>-2.15662</td>
</tr>
<tr>
<td>V1_V2</td>
<td>0.00066</td>
<td>0.00034</td>
<td>1.96663</td>
</tr>
</tbody>
</table>
Estimation of Incident Duration

1. **Simple Statistical Methods**
   - Variance Analysis – Guiliano (1989)

2. **Decision Tree**
   - Advance Project
     - Simple categorization of incident characteristics

3. **Advanced Modeling Approaches**
   - Hazard Based Duration Modeling (Nam, 2001)
     Consider duration effect
Hazard Based Incident Duration Model
- Duration Effect
- Different models for incident step (detection, response, clearance)
- Model construction based on available data by each step

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Hazard Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exponential</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>Weibull</td>
<td>$\lambda p(\ln(t))^{p-1}$</td>
</tr>
<tr>
<td>Lognormal</td>
<td>$f(t)=(p/t)\exp(p \ln(t))$</td>
</tr>
<tr>
<td>Log-Logistic</td>
<td>$h(t)=\lambda p(\ln(t))^{p-1}/[1+(\lambda t)^p]$</td>
</tr>
</tbody>
</table>
Traffic Impact Estimation

- Traffic Impact Estimation by Incident
  - Used for Response level and detour plan
  - Minimize impact by planned incident (i.e. construction, special events)
  - Reduce secondary incident

Time vs Speed Comparison
- Experiment: Seoul direction 317.0

Database
- Overhead VDS
- Temporary VDS & TCS data
- Database analysis
- Event occurrence decision

Traffic flow simulation
- Confirmed and FIA system activation
- Confirmed and FIA system activation

Traffic flow comparison
- Future traffic situation prediction
- Traffic congestion management system and traffic information provision
Incident Response and Clearance

1. Reduce Incident Detection Time
   - Communication network with various driver group
   - Using Information Technology: RFID, Ubiquitous
   - Cellular Users
   - Increase CCTV Coverage
   - Real-time video and data feed from response team

2. Traffic Management
   - Optimize VMS message
   - HAR, Cellular, Radio, Internet(hotspot)
   - Response and Clearance Manual
   - Law and Policy Change
   - Incident Team
   - Unified Command Team
Thank you.

Yesterday is History, Tomorrow is Mystery and Today is a gift; that’s why we call it Present.