Bridge management application

Hocine IMINE
Objectives

To design and to develop algorithms and softwares in order to:

1- reduce the heavy traffic effect on bridges and to avoid bridge overload.

2- decrease the infrastructure cost and increase the bridge lifetime.

3- better management of the bridges by infrastructure manager.
### System components

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensors (WIM station, loops..)</td>
<td>To collect information about the vehicles and traffic</td>
</tr>
<tr>
<td>Micro-simulation software</td>
<td>To generate traffic configurations and to define management strategy</td>
</tr>
<tr>
<td>CASTOR/POLLUX software</td>
<td>To calculate the effects of HGV on the bridge</td>
</tr>
<tr>
<td>VMS or/and fixed panels</td>
<td>To inform the drivers about actions to be taken</td>
</tr>
</tbody>
</table>
Critical configurations

Trucks meeting event
(load effect sensitivity)

Group of trucks
(fatigue and load effect sensitivity)
Traffic micro-simulation program ‘EvolveTraffic’

Generate traffic configurations and define management strategy
⇒ Traffic micro-simulation program

Characteristics:

- read data from CASTOR or SAFT format vehicle files (From WIM station);
- model roads of up to 8-lanes in width, 4 per direction;
- model one or two directions at the same time, each of up to 4 lanes;
- take into account speed limit sections of road;
- take into account gradient sections of road;
- consider overlapping gradient and speed limit sections of road;
- output Flow & Density information for specified locations on the road at specified time intervals,
- output Headway information for specified locations on the road at specified time intervals,
- output traffic composition information for specified locations on the road at specified time intervals;
Traffic micro-simulation program ‘EvolveTraffic’
Before micro-simulation

RN4 Input traffic file:
00001000526110700002842241 4121215 793814757 6213 5913 65
000020005261107000031992244 4181245 704115457 6513 6213 67
000030005261107000043824391 14 252 925 5
0000400052611070000424236 4121185 723514259 7212 6012 66

After micro-simulation

RN4 Output traffic file (modified traffic):
000012000501020800025126231 4121215 793814757 6213 5913 65
000022000501020800055709209 4181245 704115457 6513 6213 67
00003200050102080003168210 14 252 925 5
000042000501020800042295223 4121185 723514259 7212 6012 66

<table>
<thead>
<tr>
<th>Record</th>
<th>Unit</th>
<th>Format</th>
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</thead>
<tbody>
<tr>
<td>Vehicle order</td>
<td>I5</td>
<td></td>
</tr>
<tr>
<td>20000 unissued number</td>
<td>I5</td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>I2</td>
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</tr>
<tr>
<td>Month</td>
<td>I2</td>
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<td>Year</td>
<td>I2</td>
<td></td>
</tr>
<tr>
<td>Hour</td>
<td>I2</td>
<td></td>
</tr>
<tr>
<td>Minute</td>
<td>I2</td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>I2</td>
<td></td>
</tr>
<tr>
<td>Second/100</td>
<td>I2</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>dm/s</td>
<td>I3</td>
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<tr>
<td>Gross Vehicle Weight - GVW</td>
<td>kN</td>
<td>I4</td>
</tr>
<tr>
<td>Length</td>
<td>dm</td>
<td>I3</td>
</tr>
<tr>
<td>Number of Axles</td>
<td>I1</td>
<td></td>
</tr>
<tr>
<td>Weight Axle 1</td>
<td>kN</td>
<td>I3</td>
</tr>
<tr>
<td>Spacing Axle 1 - Axle 2</td>
<td>dm</td>
<td>I2</td>
</tr>
<tr>
<td>Spacing Axle 8 – Axle 9</td>
<td>dm</td>
<td>I2</td>
</tr>
<tr>
<td>Weight Axle 9</td>
<td>kN</td>
<td>I2</td>
</tr>
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</table>
Effects of the traffic on the bridge

POLLUX-Software

Traffic Influence lines

Traffic

Determination of DDN and Rain-flow histograms
(Level crossing) DDN ➔ calculation of extremes values
Rain-flow ➔ fatigue calculation (S-N curve)

The damage by load effect: depends on the combination of bridge characteristics and the intensity of the traffic configuration and concerns essentially prestressed concrete bridges (VIPP).
Level crossing (DDN) histograms using RN4 traffic data
Rain-flow histograms
## Fatigue results

<table>
<thead>
<tr>
<th></th>
<th>Real RN4 traffic (11days)</th>
<th>Simulated RN4 traffic (11days) Gap=70m</th>
<th>Simulated RN4 traffic (11days) Gap=70m - Weight limitation to: 39tonnes/40t/45t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-71</td>
<td>C-90</td>
<td>C-71</td>
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<tr>
<td>Auxerre mi1</td>
<td>281.59</td>
<td>8665.56</td>
<td>296.28</td>
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<tr>
<td>Beaucaire mi3</td>
<td>13.50</td>
<td>45.39</td>
<td>13.56</td>
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<tr>
<td>Joigny mi1</td>
<td>259.34</td>
<td>2630.55</td>
<td>432.85</td>
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<tr>
<td>Millau mi1</td>
<td>1554.44</td>
<td>24449.34</td>
<td>58320.11</td>
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<tr>
<td>Jargeau mi3</td>
<td>16.49</td>
<td>59.53</td>
<td>17.91</td>
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<td>Kervitous mi1</td>
<td>198.76</td>
<td>5549.25</td>
<td>205.04</td>
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<tr>
<td>Libourne mi1</td>
<td>41.49</td>
<td>320.71</td>
<td>43.97</td>
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<tr>
<td>Layrac mi2</td>
<td>43.98</td>
<td>246.85</td>
<td>72.06</td>
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</tbody>
</table>
Bridge Management
Dynamic Effects

Stefan Deix

FEHRL
Dynamic Bridge Vehicle Interaction

- Full bridge vehicle interaction
- Transient finite element analysis
Dynamic Bridge Vehicle Interaction

- Dynamic influence
- Increased material stresses
- Dynamic amplification factor (DAF)
Vehicle Model

- 17-DOF HGV model
- 40 ton middle European truck
- 60 ton northern European truck
Bridge Models

- Reinforced concrete plate
- PC prefabricate girder
- Steel orthotropic
- Composite
- Spans 8 – 40 m (short span)
Transient Finite Element Analysis
Impact of Different HGV Models

20m composite bridge

30m composite bridge

![Graph 1: Bridge stress for 20m composite bridge](image)

![Graph 2: Bridge stress for 30m composite bridge](image)
Impact of Different HGV Weights

30m composite bridge

30m steel bridge

Heavier vehicles have lower DAF
Austrian bridge “Freudenauer Hafenbrücke”

Prestressed concrete 2-box girder

Spans: 60 m, 90 m, 60 m

Lanes: 2

Constructed in: 1958
Test Plan

Laservibrometer measurement points

Strain gauges

Accelerometers

Position in cross-section
Test Equipment

- Laservibrometer head
- Laservibrometer measured point
- Strain gauge
- Accelerometer
Measurement Results

- L1 displacement [mm] for Lane 1
- S1 strain [μm] for Lane 1
- Dynamic Stress Amplification Factor for Lane 1
Model Validation

Predicted DAF higher than measured
Test site in Angers, France

Evaluation of the drivers behavior with respect to the traffic management instructions

Questionnaire aims to specify drivers waitings compared to the context of the experimentation and to define the message to be posted on the traffic sign.

This questionnaire was made on the rest area of A6 motorway in France, with 55 drivers of various nationalities and various ages.
Experimental Site SAROT

A87 nord in Angers (France)

- Speed measurement
- Inter-vehicular time measurement
- Category detection (VL, PL)
- Speed variation measurement (ps12-ps13)
Used material

Electromagnetic loops

Laser sensors

Traffic panel

Traffic signs

Masked 110km/h panel

Masked 110 km/h signs
At 90 km/h, the distance covered in 2 seconds is about 50m.

The chosen gap instruction for the experimentation, was fixed at 70m, so that it:

- is sufficiently different from the Highway code regulation, pointed out above, to be able to measure the user’s variation behavior;

- remains "acceptable" by the drivers (questionnaire is realized and the results are given in a report).
2 steps:

1st step:
The experimentation is done for the period: 01/09/08 to 28/09/08 on SAROT experimental site in Angers without panels. It’s used as reference, in order to better estimate the evolution of the HGV driver’s behaviors.
2nd step:

The second series extended over the two last weeks of January 2009 from 12/01 to 30/01, after installing the modified panels relating to the instruction of specified gap (70m).
### RESULTS

**Before the indication:**

<table>
<thead>
<tr>
<th>3rd treatment</th>
<th>Nbr of treated HGV</th>
<th>Moyenne of daily total Ti</th>
<th>Nbr of HGV of which Ti&lt;2s</th>
<th>% of HGV of which Ti&lt;2s</th>
<th>Mean of Ti &lt;2s</th>
<th>Nbr of HGV of which gap&lt;50m</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS11</td>
<td>42105</td>
<td>70.43</td>
<td>2584</td>
<td>6.14%</td>
<td>1.444</td>
<td>2882 (6.84%)</td>
</tr>
<tr>
<td>PS12</td>
<td>36401</td>
<td>84.19</td>
<td>1174</td>
<td>3.23%</td>
<td>1.523</td>
<td>1466 (4.02%)</td>
</tr>
<tr>
<td>PS13</td>
<td>48132</td>
<td>64.86</td>
<td>2282</td>
<td>4.74%</td>
<td>1.537</td>
<td>2800 (5.82%)</td>
</tr>
</tbody>
</table>

439236 recordings over 19 days (September 2008)

**PS12:**

→ 36401 trucks ≈ 11% of traffic

→ 1466 ≈ 4.02% of heavy lorries don’t respect the gap of 50m
RESULTS

After the indication:

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<tr>
<th>3rd treatment</th>
<th>Nbr of treated HGV</th>
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<th>Nbr of HGV of which gap&lt;50m</th>
<th>Nbr of HGV of which gap&lt;70m</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS11</td>
<td>31384</td>
<td>75.71</td>
<td>1429</td>
<td>4.35%</td>
<td>1.41</td>
<td>1609 5.12%</td>
<td>2637 8.40%</td>
</tr>
<tr>
<td>PS12</td>
<td>64753</td>
<td>86.67</td>
<td>466</td>
<td>4.10%</td>
<td>1.55</td>
<td>4889 7.55%</td>
<td>8059 12.44%</td>
</tr>
<tr>
<td>PS13</td>
<td>67099</td>
<td>72.38</td>
<td>2641</td>
<td>3.77%</td>
<td>1.52</td>
<td>4331 6.45%</td>
<td>7575 11.29%</td>
</tr>
</tbody>
</table>
467099 recordings over 15 days (January 2009)
→ 64753 trucks ≈ 14% of traffic
→ 4889 ≈ 7.55% of heavy lorries don’t respect the gap of 50m
→ 8059 ≈ 12.44% of heavy lorries don’t respect the gap of 70m
The data analysis shows that:

- Some of drivers do not respect the inter-vehicular time of 2 seconds (between 2 light vehicles) and the 50 meters between heavy lorries imposed by Highway Code.

- A significant number of drivers have changed behavior in the presence of the panels of "Gap 70m".

- The two measurements series were not successive in time (flow of HGV). The traffic flow is not the same. The comparison can then be influenced.
- It’s interesting in the future to do the 2 tests successively.

- The installation of traffic management and control system to regulate speeds and interdistances need the deployment of high technology information services.

- The lawful framework must be simplified, returning it thus more comprehensible and thus better applied and controlled and supporting the emergence of automated solutions;

- The co-operation with the foreign (European) administrations must be reinforced

- Test in real time, the bridge management strategy adding WIM system, VMS and bridge.