Development And Testing of a 2-Dimensional Multi-Vehicle Bridge-WIM Algorithm

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Presentation Layout

- Project Aims
- Experimental Test Sites
- Influence Line / Surface Generation
- Experimental Results
- Multi-Vehicle Events
- Current Work
- Conclusions

Project Aims

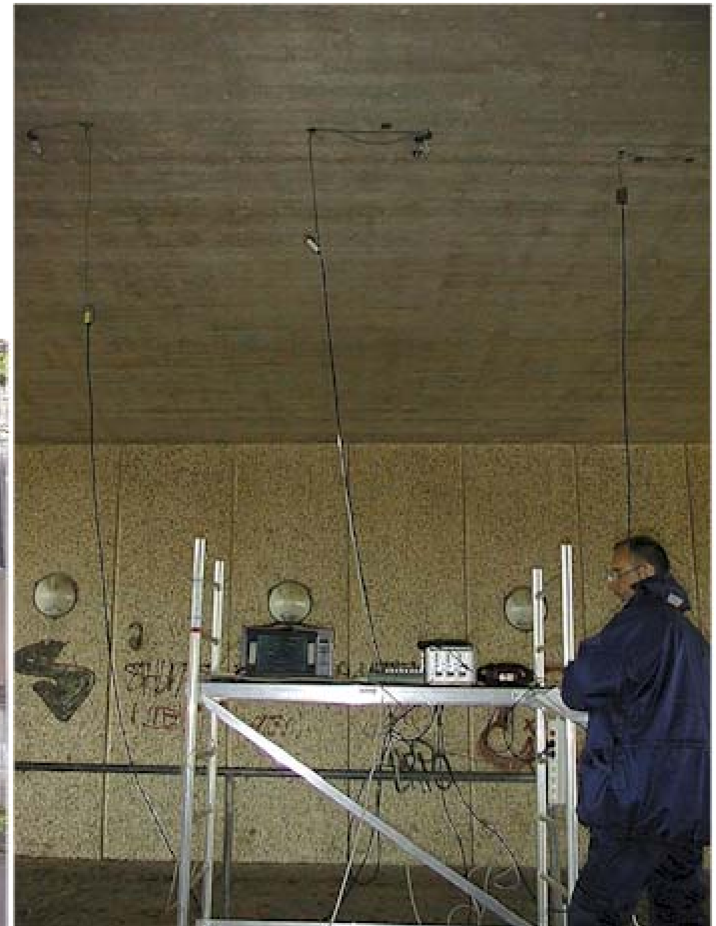
Advance Bridge-WIM systems through:

- Optimum influence line generation
- Adoption of 2-D influence surface:
  - Improve accuracy
  - Cater for multi-vehicle events
  - Supply vehicle transverse position data
- Validation through experimental tests and Finite Element Model

Stockholm Test Site

Östermalms IP:

- 10m span frame bridge
- Heavily trafficked area
- Good road surface



Kramfors Test Site

- 14m span frame bridge
- 1 lane of traffic in each direction
- Rise in approach of one lane

- Carried out in conjunction with SiWIM

Influence Line Generation

Influence Line very important for accurate results

Previous approaches included:

- Modification of theoretical influence line
- *'Point-by-point'* manual method

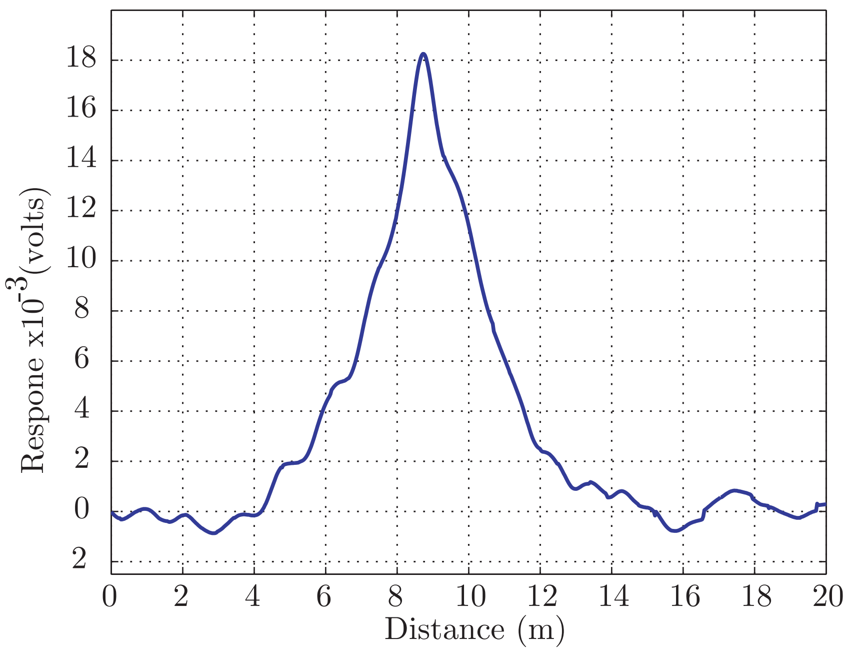
New development:

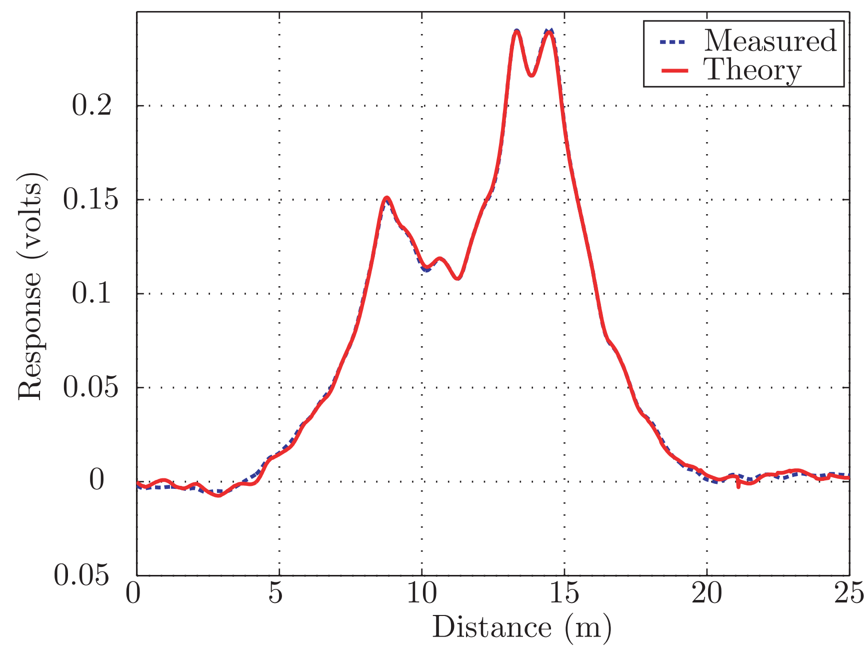
- Automatic *'matrix type'* method
- Finds optimum influence line to minimise:

$$E = \sum_{k=1}^{K} \left[M^{M}(x_k) - M^{T}(x_k) \right]^2$$

Sample Influence Line

- Influence line derived from sample crossing of 3-axle truck

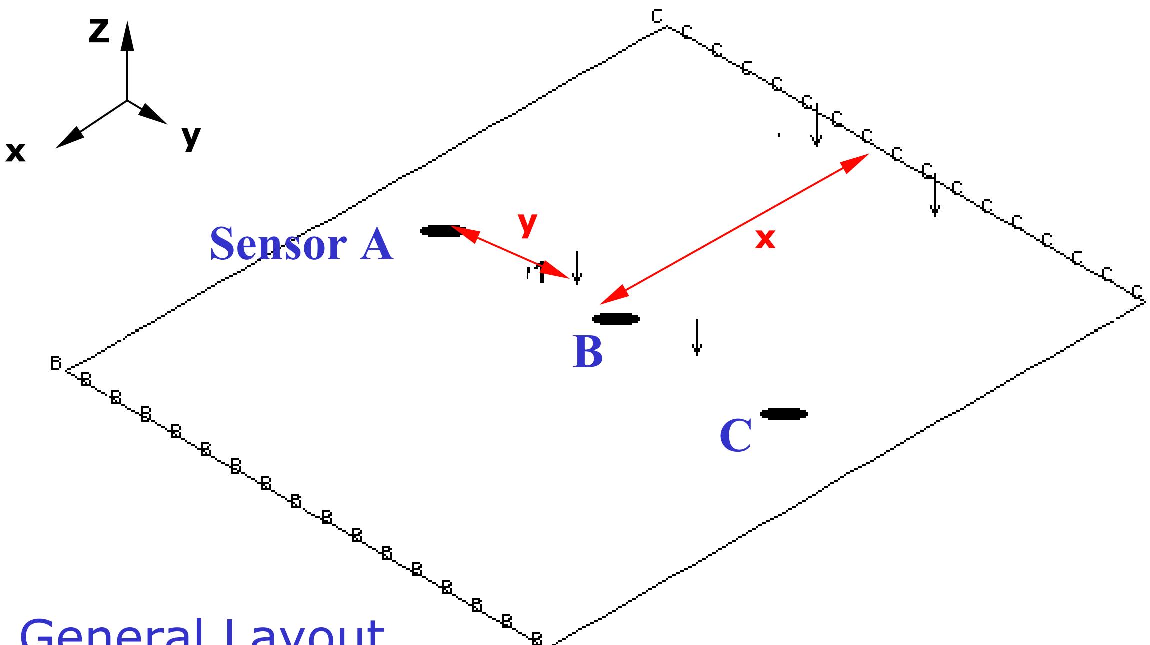




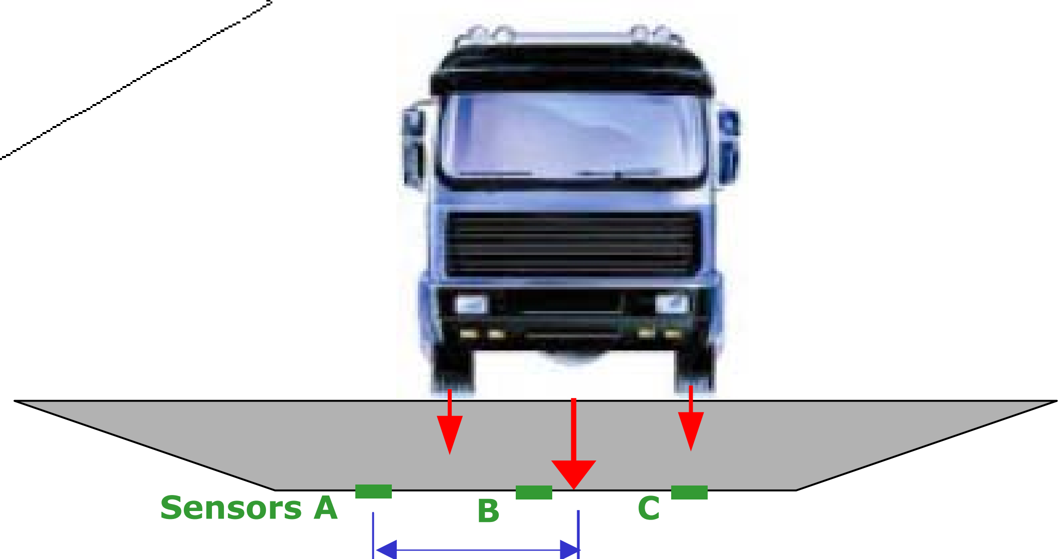
- Corresponding plot of 'Measured' vs 'Theory' responses

Influence Surface

$$E = \left[M_A^M(x,y) - M_A^T(x,y) \right]^2 + \left[M_B^M(x,y) - M_B^T(x,y) \right]^2 + \left[M_C^M(x,y) - M_C^T(x,y) \right]^2$$



General Layout



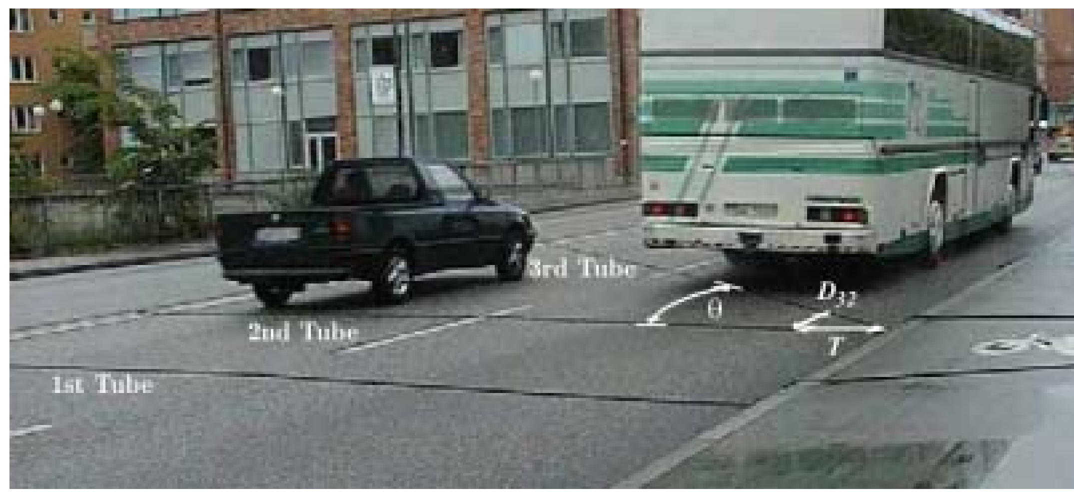
® Truck graphic redrawn from Vägverket 'Legal Loading 1999'

Influence Surface Calibration

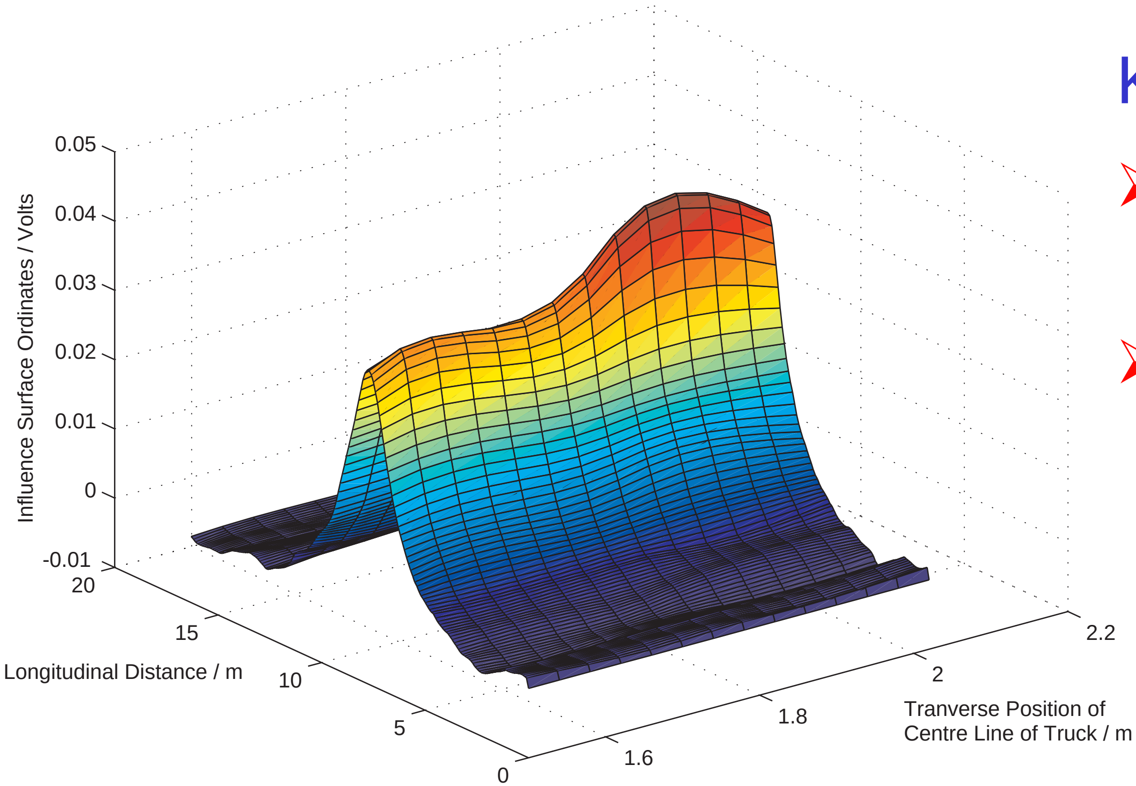
Transverse position of calibration truck required:

- Film of sand placed to record tyre imprint
- Reflective strips used with digital video camera

- Third diagonal axle detector

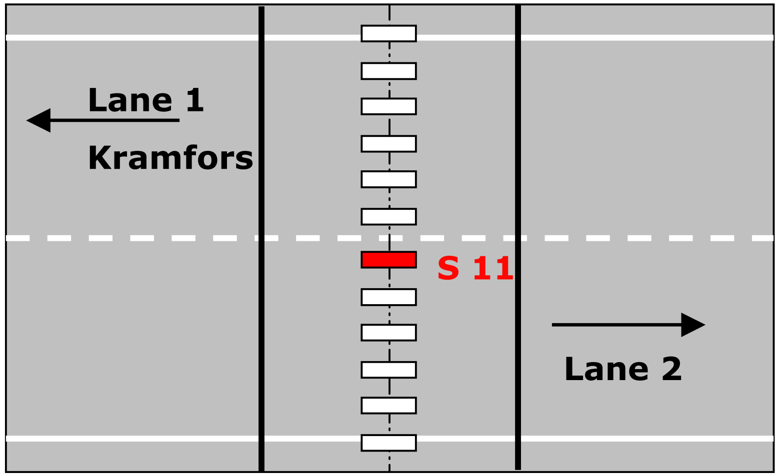


Sample Influence Surface



Kramfors bridge:

- Influence surface for Sensor 11
- Derived from crossings in Lane 2



® Bridge layout graphic redrawn from SiWIM

2-Dimensional Algorithm

- Traditional algorithm used to find initial values, y_o:

  y_o = { velocity, axle distance, axle weight }

- Values input into optimisation procedure to minimise:

$$E(y) = \sum_{j=1}^{S} \sum_{k=1}^{K} \left[M_j^M(x_k) - M_j^T(x_k) \right]^2$$

- Transverse position of crossing vehicle supplied as output

Östermalms IP Results

Single vehicle events

`Class' takes account of `full repeatability' test conditions

1-D algorithm:

Criterion	Number	Mean (%)	Std Dev (%)	Class
Gross Weight	23	-0.18	2.75	**B(10)**
Group of Axles	11	-0.08	2.51	**B+(7)**
Single Axle	35	-0.39	3.32	**B(10)**

2-D algorithm:

Criterion	Number	Mean (%)	Std Dev (%)	Class
Gross Weight	23	-0.37	1.01	**A(5)**
Group of Axles	11	0.12	0.52	**A(5)**
Single Axle	35	-0.87	1.77	**A(5)**

Improvement in results…

Kramfors Results

Single vehicle events

1-D algorithm:

Criterion	Number	Mean (%)	Std Dev (%)	Class
Gross Weight	19	-0.64	1.99	**B(10)**
Group of Axles	57	0.37	3.01	**B(10)**
Single Axle	19	-7.39	3.76	**D+(20)**

`Class' takes account of `full repeatability' test conditions

2-D algorithm:

Criterion	Number	Mean (%)	Std Dev (%)	Class
Gross Weight	9	0.06	1.00	**A(5)**
Group of Axles	27	0.96	2.02	**B+(7)**
Single Axle	9	-5.94	2.70	**C(15)**

Improvement in results…

Multi-Vehicle Events

Disadvantage of existing algorithms:

- Accuracy affected when car / truck present during measurment
- Suitable length of structure and traffic density related

Östermalms IP bridge:

- High probability of Multi-Vehicle events

Multi-Vehicle Algorithm

Multi-Vehicle algorithm:

- Important to have accurate initial data
- Optimisation function extended to find:

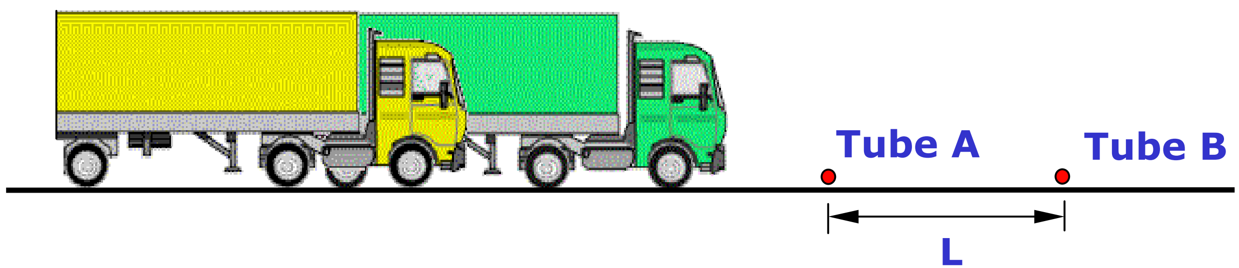
  y = { vel, axle dist, axle weight, trans. psn., time diff }

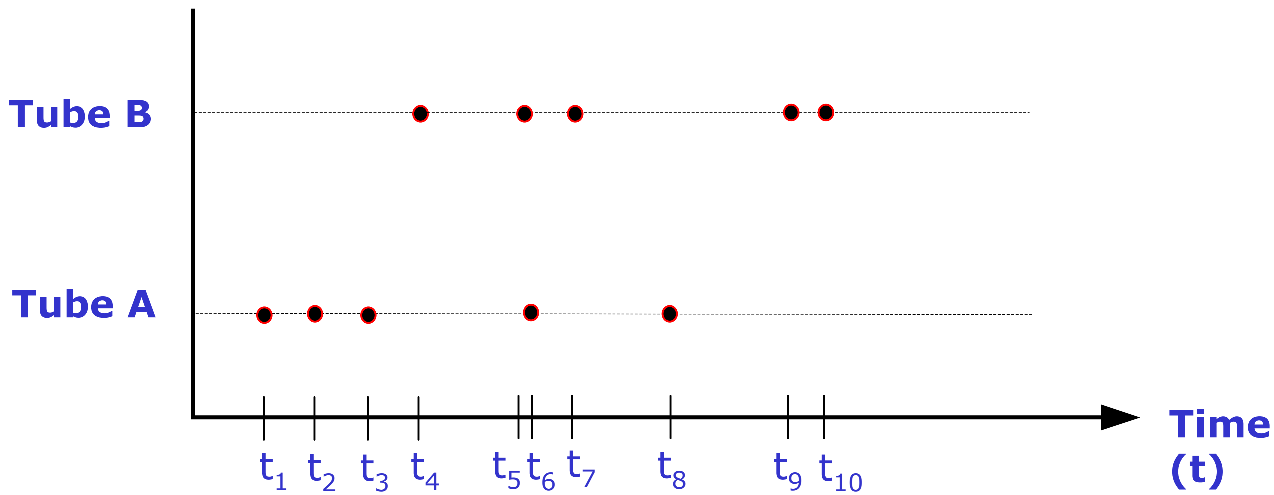
Test at Östermalms IP:

- Most difficult scenario of two trucks travelling side-by-side dealt with

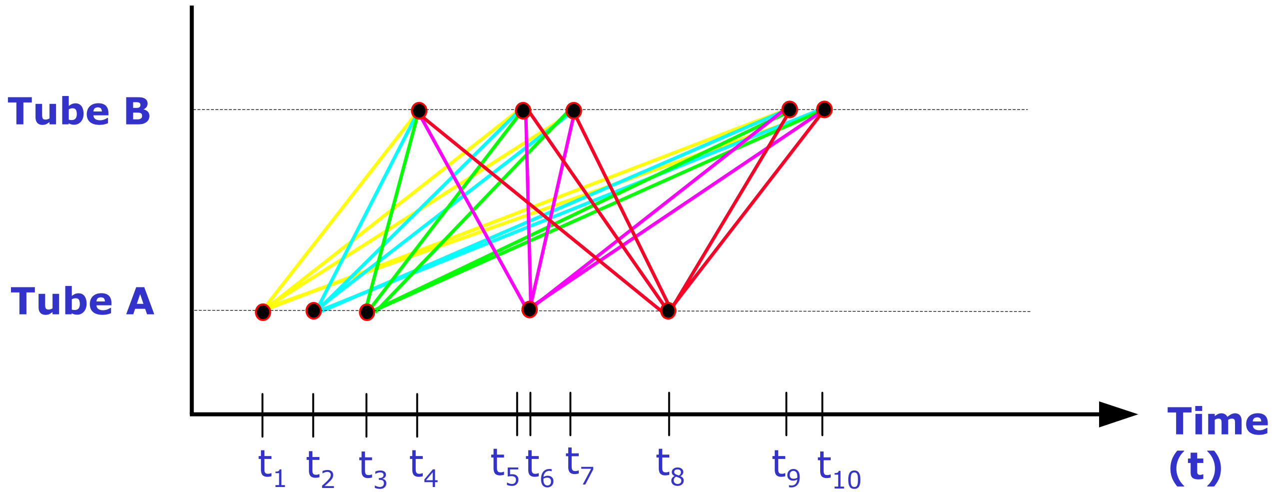
Multi-Vehicle Events

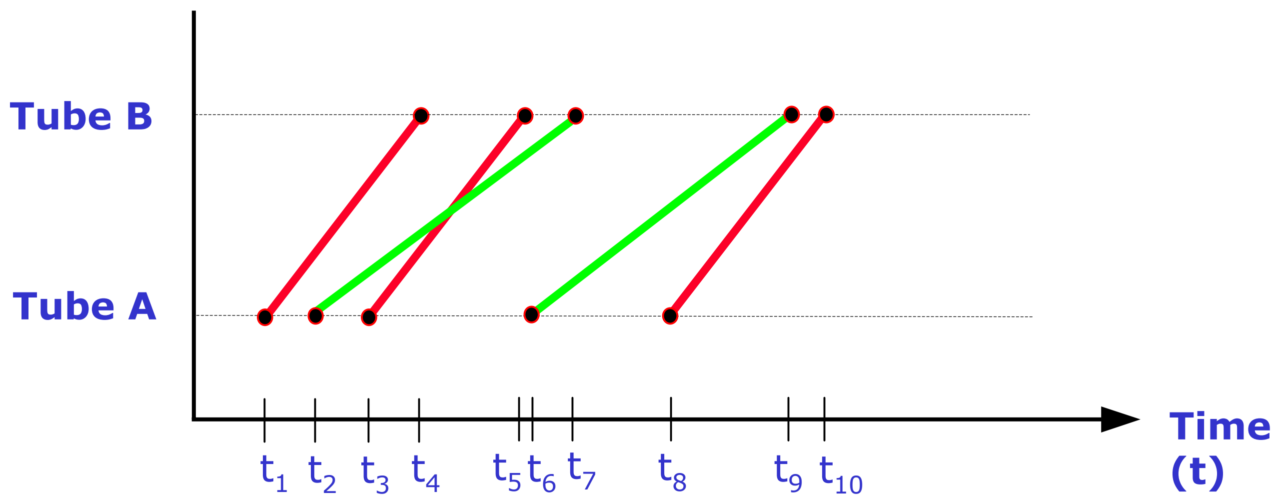
Important to distinguish individual vehicles





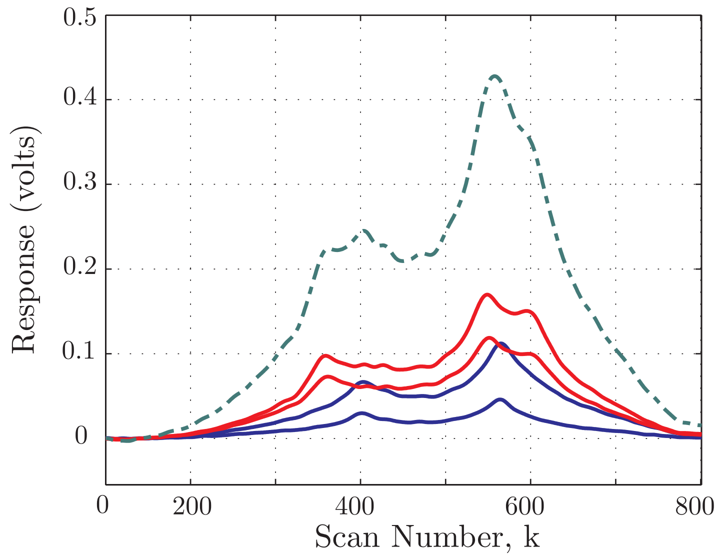
Multi-Vehicle Events





$V_1 = L / (t_4 - t_1)$ and $S_{11} = V_1 / (t_3 - t_1)$ etc...

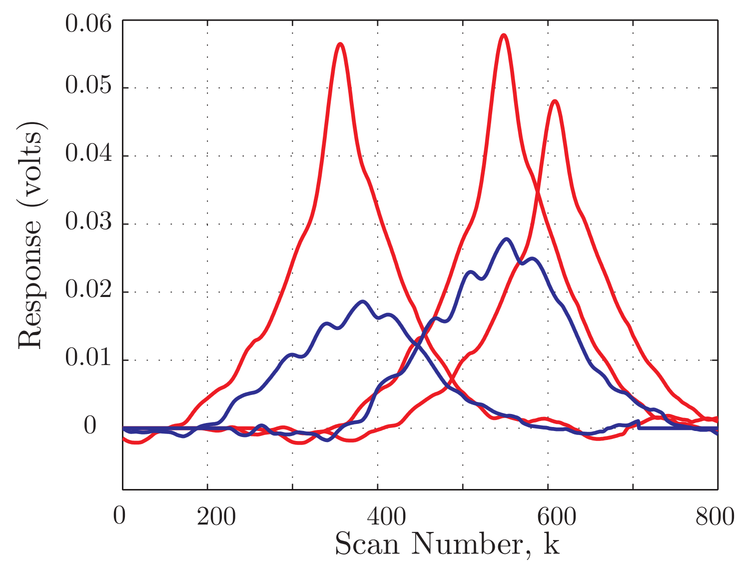
Multi-Vehicle Algorithm



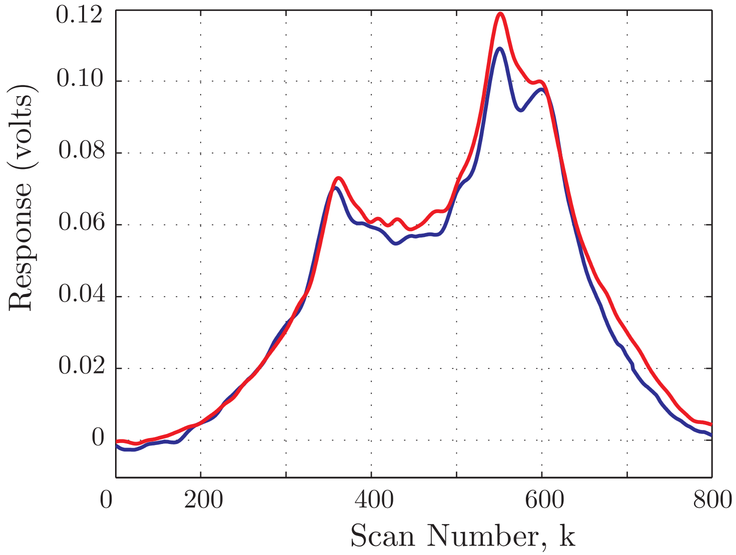
- Difficult to distinguish individual vehicles from total strain response…

- Influence surface allows each axle to be accounted for…

- Algorithm varies each parameter to minimise objective function…



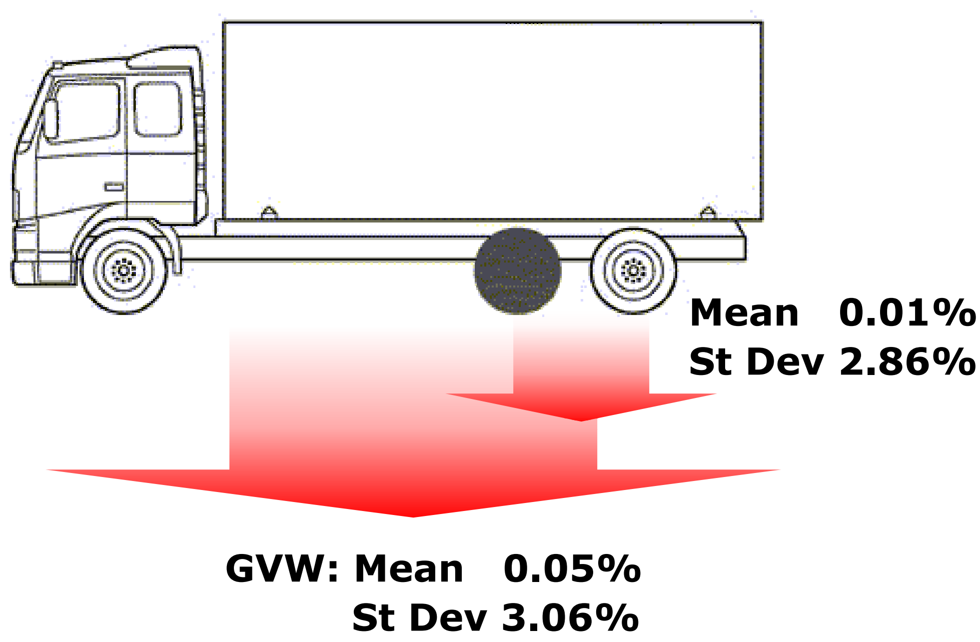
Multi-Vehicle Results



- i.e. fit the measured and theoretical curve of each sensor…
- Results output once function minimised

Multi-vehicle errors

- % difference between B-WIM and Static weights



®Truck graphic redrawn from AB Volvo

Multi-Vehicle Results

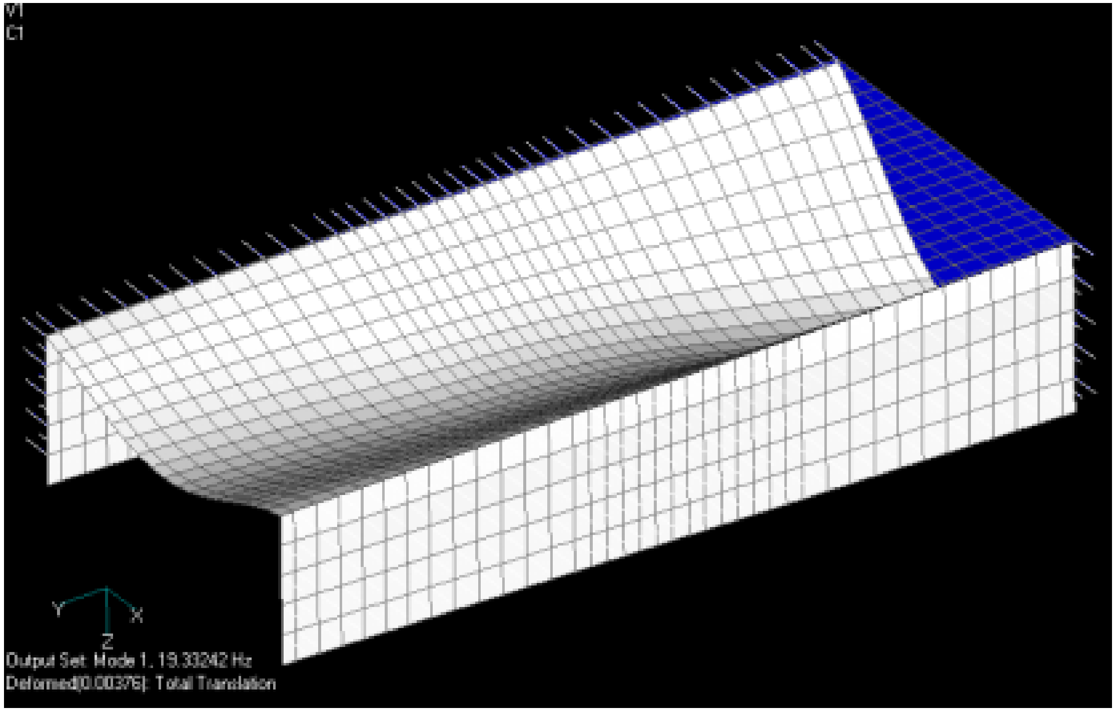
Östermalms IP Bridge

Single (23No.) and Multi-Vehicle (10No.) events

Criterion	No.	Mean (%)	Std Dev (%)	Class
Gross Weight	33	-0.10	1.87	**B+(7)**
Group of Axles	16	0.08	1.54	**A(5)**
Single Axle	50	-0.45	3.33	**B(10)**

Current Work

- Detailed FEM model of Östermalms IP bridge constructed with UCD
- Parameters varied to match measured response



- 'Self-Calibration' method under development

Conclusions

- Influence Line generation fully automated
- Influence Surface shown to improve results
- Transverse position of crossing truck available as additonal output
- Multi-Vehicle events accounted for

- Current work hopes to valiate experimental results and allow 'Self-Calibration'