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PORTABLE BRIDGE WIM DATA COLLECTION STRATEGY FOR SECONDARY ROADS



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Abstract

A common method of collecting traffic loading data across a large road network is to use a network of permanent pavement-based WIM systems. An alternative is to use one or more portable Bridge Weigh-In-Motion systems which are moved periodically between bridges on the network. To make optimum use of such a system, a suitable data collection strategy is needed to choose locations for the system. This paper describes a number of possible strategies which the authors have investigated for the National Roads Authority in Ireland. The different strategies are examined and their advantages and disadvantages compared. Their effectiveness at detecting a heavy loading event is also investigated and the preferred approach is identified.

Keywords: Bridge, Weigh-In-Motion, WIM, B-WIM, BWIM, Data, Strategy, Secondary Roads, Traffic, Loading.

Résumé

Une méthode usuelle pour recueillir des données de trafic sur un réseau routier étendu est d'utiliser un réseau de stations de pesage intégrées dans la chaussée. Une alternative est d'utiliser le système de pesage par pont instrumenté qui est portable en étant transporté à intervalles réguliers d'un pont à l'autre. Pour optimiser l'utilisation d'un tel système, une stratégie d'utilisation de ce système doit être établie. Ce papier un certain nombre de stratégies que les auteurs ont étudiées en s'intéressant au réseau routier Irlandais. Pour chaque d'entre elles, leurs avantages et leurs inconvénients sont présentés. Leur efficacité à détecter des surcharges est également étudiée et la meilleure démarche est identifiée.

Mots-clés: Pont, pesage en marche, WIM, B-WIM, données, stratégie, routes secondaires, trafic, charges.

1. Introduction

Traditionally, to collect loading information on an extensive road network, it has been necessary to install multiple permanent Weigh-In-Motion (WIM) systems. This is an expensive investment and causes disruption to traffic during installation and maintenance. With the recent advances in Bridge WIM (B-WIM) technology, a feasible alternative is to use one or more portable B-WIM systems which can be moved between bridges throughout the road network. These systems can be easily moved and the predominance of nothing-on-road axle detection techniques (OBrien et al, 2008) means that they can be installed with little or no disruption to traffic. By moving a B-WIM system at regular intervals, a picture of the distribution of traffic loading throughout a road network can be obtained.

The value of the data obtained from a portable B-WIM system depends on the locations where it is installed. A data collection strategy is therefore needed to put the B-WIM system to best use. This strategy should allow an accurate estimation of the general traffic loading throughout the network to be obtained but can also be altered to target "problem" areas.

The idea of using a data collection strategy to locate weighing operations is not a new one. In Montana, USA (Stephens et al, 2003) data gathered from an extensive WIM network was used to choose locations for enforcement operations for the following year. Strategies were developed for processing the WIM information and the areas to be targeted by enforcement were determined on a monthly basis. It is estimated that \$500,000 of pavement damage per year was saved. However, the strategy used in Montana is not directly comparable as it was used for locating enforcement operations rather than sites for WIM data collection.

This paper is based on work which was carried out for the National Roads Authority (NRA) in Ireland. The road network in Ireland includes 1,187 km of motorways and serves a total area of approximately 70,000 km² divided into 26 counties (administrative regions). The NRA plans to install permanent pavement-based WIM systems to gather traffic loading data on Ireland's major inter-urban routes. This study investigates the additional use of a portable B-WIM system to gather data on 15,000 km of other roads which will not be covered by the permanent WIM systems. These include secondary, regional and legacy national primary roads (i.e., former national primary roads which, although still in use, have been superseded, typically by motorways). This B-WIM system would be moved around the country regularly and a method of choosing locations for the installations is needed. Various data collection strategies are examined in order to identify the optimal strategy.

2. Review of Irish Road Network

Representative samples of road in one county – Co. Kildare, which has an area of 1,693 km² – were examined in order to get an idea of the number of bridges which would be suitable for B-WIM on legacy national primary, national secondary and regional roads. An NRA database was used to examine bridges on a legacy national primary road and on two selected national secondary roads. Site visits were made to a number of regional roads and their bridges surveyed - see Figure 1.

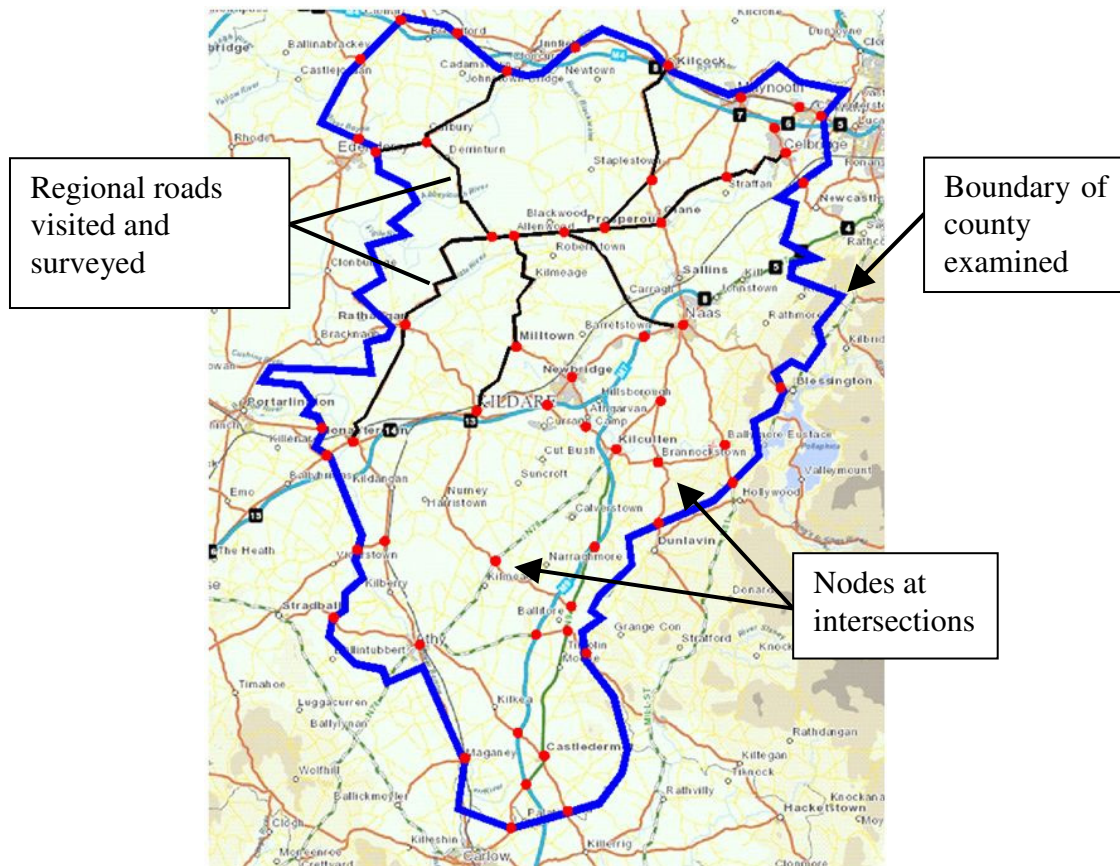


Figure 1 – Regional Roads Visited and Surveyed and Nodes at Intersections of Relevant Roads

2.1 Suitability for B-WIM

The suitability of a bridge for B-WIM (Hitchcock et al, 2011; Žnidarič et al, 1999) is assessed using four criteria:

1. **Construction material:** Steel is best but reinforced concrete bridges can also be used. Masonry and other arched bridges were deemed unsuitable.
2. **Access:** Soffit of the bridge must be accessible. Bridges located over fast flowing rivers or busy roads/railways were deemed unsuitable.
3. **Span:** Short, simply supported, spans are preferred but continuous bridges can also be used.
4. **Skew:** Ideally the bridges should not be skewed although some skew can be allowed for in the B-WIM software.

Using the four criteria listed above, the suitability of bridges for a B-WIM system, was assessed and bridges divided into the following categories:

- Category 0: Not Feasible – Bridge not suitable for B-WIM installation
- Category 1: Feasible – Possible to install system, but with some complications
- Category 2: Ideal – System could easily be installed on this bridge

2.2 Suitability of Irish Bridges

Tables 1 and 2 give summary information on the bridges examined and their suitability for B-WIM. Ireland has a relatively high proportion of masonry arch bridges (Gibbons and Fanning, 2011), which are unsuitable for B-WIM. The proportion of B-WIM suitable bridges in

countries with fewer masonry arch bridges may be higher than in Ireland. Photographs of bridges in each of the three categories are provided in Figure 2.

Table 1 - Summary of Bridges on each Road Type Examined and Suitability for B-WIM

Road Type	Length Examined (km)	No. of Bridges	Cat. 0	Cat. 1	Cat.2
Legacy Primary	116	41	34	5	2
Secondary	62	47	39	6	2
Regional	122	44	36	7	1

Table 2 - Suitability of Bridges Examined for B-WIM System

Road Type	% Suitable for B-WIM (Cat. 1 or 2)	Average Distance Between Suitable Bridges (km)
Legacy Primary	17	17
Secondary	17	8
Regional	18	15



Figure 2 – Samples of the Bridges Examined

3. Data Collection Methods

Different methods for choosing the roads on which the B-WIM system would be installed were investigated. An ideal method would cover as much of the network as possible while also capturing significant loading events.

3.1 Length Method

This method identifies the individual roads being examined according to their road number. Each road is then divided into sections about 15 km in length. A section of road is picked randomly – with equal probability of all such sections being selected – and the B-WIM system installed on a suitable bridge on this section of road. If a suitable bridge is not

available on that section, then the nearest suitable bridge on the same road is used. The B-WIM system is left at each site for a week before being moved to another randomly chosen section of road. An installation period of a week was chosen so the system could measure vehicle weights on many different roads and a general picture of the loading on the network of roads could be obtained. The average distances between suitable bridges shown in Table 2 suggest that a majority of the sections selected should either contain a suitable bridge or be reasonably close to one.

Once a section of road has been chosen it is either excluded from future selections or included. If it is excluded:

- Every section of road in the country will be covered in a fixed time.
- Existing sources of heavy loads that repeatedly use the same roads will be caught in that fixed time.
- If a new source of heavy loading emerges on a route that has already been picked, it will not be detected until the cycle of all roads is complete.

If selected road sections are included as candidates for future selection:

- It will not be possible to guarantee that every road section in the country will be selected in a fixed time period.
- New and emerging sources of heavy loads are just as likely to be selected as existing sources.

Given the extremely long cycle to cover all sections (20 years based on an estimated 15,000 km of roads), the latter approach is recommended. It is also recommended that the selection of road sections should take account of their relative Average Daily Truck Traffic (ADTT), with busier roads being selected more often.

3.2 Node Method

This method involves using nodes to divide up all the roads being examined into segments. A node is located at any intersection of these roads. The network is then divided up into sections, with each section beginning at one node and finishing at the next node encountered. Sections are then randomly chosen and the B-WIM system installed on a suitable bridge on this section of road. If no suitable bridge is found then another section is randomly chosen. Sections with higher truck volumes can be weighted, as for the length method, to increase their probabilities of selection in proportion to their ADTT's. This method was applied to County Kildare and 56 nodes were found – see Figure 1 – which resulted in 75 sections of road. Assuming each of the 26 counties contains the same number of road sections, we get an approximation of 1,950 road sections for the whole country of Ireland.

Large loads will travel the full length of the section of road between each pair of nodes, with the exception of the sections at the beginning and end of their journey. The aim of this method then is to divide the network into stretches of road which experience near uniform loading. The disadvantage of this method is that it results in more road sections than the length method and would take nearly twice as long to examine every section in the country. These sections of road also tend to be short, with lengths varying between about 2.5 km and 15 km, based on the data collected for the county examined. Therefore when a short section is chosen it is unlikely to contain a suitable bridge, which leads to some inconsistencies.

3.3 Targeted Data Collection

This method involves using the portable B-WIM system to solely target known or perceived sources of heavy loads. The system is moved around the country on a weekly basis or as required, between areas that were identified as likely to experience overloaded vehicles. If overloaded vehicles are detected on a road, the police could then be asked to target this route and set up checkpoints or to visit repeat offenders. There is some anecdotal evidence that this kind of approach is working well elsewhere in Europe. Sources of overloading may include:

- Precast Concrete Manufacturers
- Steel Suppliers/Manufacturers
- Logging areas and Sawmills
- Ports
- Crane Suppliers/Manufacturers

A targeted data collection approach could also be used to examine sections of road:

- Where abnormal road surface deterioration is experienced. Such roads maybe identified using local knowledge or by comparing yearly road roughness data.
- With high ADTT.
- Which are alternatives to tolled motorways.
- Where there is concern about the condition of a particular bridge.
- Which are close to a source of, or destination for, heavy vehicles.

The advantage of this method is that it is much more likely to capture extreme events than the length and node methods. The disadvantage is that the data collected is biased and does not give an indication the underlying general trend on the road network.

3.4 Case Study

To get an indication of the ability of these methods to capture extreme loading events or trends, a hypothetical scenario was created and examined using each approach. The scenario considered that a major heavy vehicle destination exists at a chosen location (Cavan in Figure 3) and that once a week, heavy trucks travel from Athlone to Cavan. These weekly trips are assumed to continue for one year. The route was chosen as it does not contain any inter-urban roads and uses only roads which are relevant to this report. The route covers 81 km of regional and national secondary roads – see Figure 3. It is assumed that a single portable B-WIM system is employed to cover all 26 counties.

Length method

As the route covers 81 km of road, it will contain 5.4 (81/15) road sections according to the length method. Based on an estimated total length of 15,000 km, there are 1,000 segments of road in the country. The probability of successfully capturing the event at least once in one year (50 working weeks) is calculated from basic probability concepts (Ang and Tang, 2007) using Equation (1):

$$P(\text{Capturing Event}) = p + qp + q^2p + q^3p + \dots \dots \dots - q^{49} p \tag{1}$$

where: p = the probability of any of the 5.4 sections being measured in a given week
 q = the probability of one of the sections not being measured in a given week

Using Equation (1), the probability of this Athlone/Cavan event being captured by the length method is 23.7%.



Figure 3 – Hypothetical Route Examined - Route Highlighted and Nodes Shown

Node method

The route in question was found to contain 10 road segments – see Figure 3. For the purposes of this study, the crude assumption is made that each of these road segments contains a suitable bridge. In reality it is unlikely that this would be the case. It is also estimated, by extrapolating from the county examined, that there are 1950 road sections in the country. The probability of this event being captured by the node method is calculated as 22.7%.

Mixed Targeted and Random Approach

The random (length and node) methods give better statistical information on the complete distribution of loading in the target networks. Targeting likely locations of overload on the other hand is statistically biased – the data collected tends to represent the upper end of the true loading distribution and its use could result in excessive conservatism in pavement design or bridge assessment. However, targeting has the advantage that it may result in a reduction in the extent of overloading which saves costs in the pavement maintenance budget in particular. A compromise between these two approaches is to divide the B-WIM system equally between random and targeted approaches. Assuming that the hypothetical event is not among the routes targeted, the probability of it being detected is reduced to 12.7% for the length method or 12.1% for the node method. Doubling the number of B-WIM systems would result in nearly double the probability of success while also allowing one sensor to be permanently used for the targeted approach.

4. Conclusions and Recommendations

The length and node methods perform similarly in the case study, i.e., each gives a similar probability of detecting the repeated overloading scenario. As the length method is easier to understand and to implement, it is recommended in preference to the node method. To avoid problems associated with the long cycle, it is recommended that repeat selections be allowed.

It is recommended that the length method be operated for half the operating time of the B-WIM system and targeted data collection for the other half of the time. This addresses the shortfalls of the methods discussed in Section 3, as it targets problem areas while also examining the loading conditions on typical legacy national primary, national secondary and regional roads.

The initial capital cost of a portable B-WIM system is similar to that of a permanent WIM installation. This portable B-WIM proposal requires weekly reinstallations and recalibrations and would have relatively high operational costs compared with a single permanent system. Despite the cost of these weekly reinstallations, if the aim is to cover an entire secondary road network, the portable B-WIM proposal is hugely less expensive than a network of permanent systems.

5. Acknowledgements

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