WHERE TO PLACE WIM STATIONS? THE BRAZILIAN APPROACH INCLUDING A NOVEL DATA-DRIVEN SPATIAL DECISION SUPPORT SYSTEM

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ABSTRACT

The current most advanced WIM systems distributed worldwide have already proven their capacity for weight enforcement. The question of whether or not precise weight measurements are possible in highway speeds is no longer open, as many systems have shown good results in this direction. Now, other questions start to arise in the industry. One of the main questions is: in large road networks, where should we install WIM sensors so that they achieve their maximum efficiency? It is proven that the enforcement system as a whole is ineffective if improper locations are chosen, and effective if the locations are well chosen. In this paper, the method that is currently being used by the Brazilian National Land Infrastructure Department (DNIT) is presented. It is a spatial decision support system (SDSS) that includes a multi-criteria method developed to facilitate decision-making in this process by summarizing a set of important information into a single index named IVFP. The adopted philosophy is not to make the decision on behalf of the road entity but, rather, to provide the planner with accessible information regarding the road network and a unified index that highlights segments for weight enforcement. The Brazilian approach is presented so that it can serve as a starting point for the international community, as this is a problem that will become common in the next few years.

Keywords: Transportation Systems, Weigh enforcement, Equipment placement, Multi-criteria method.

1. INTRODUCTION

The Weigh-in-Motion (WIM) technological evolution to high-speed weighing over the last few decades is presently showing signs of becoming well established around the world. The technical and the regulatory challenges that are presented are currently being faced by the private, institutional and academic sectors, so much so that vendors already have advanced high-precision high-speed WIM systems, and countries around the world are actively seeking a transition in their laws to allow direct weight enforcement with WIM.

In this moment that the systems are ready for practical use for high speed weight enforcement, other questions arise, such as how to select the most appropriate locations to place WIM stations in road networks, especially extensive ones. This matter is crucial for road system planners because, in selecting the most appropriate locations for the stations, the enforcement network can create a large impact on overweight rates with a relatively small number of stations, whereas with inappropriate locations (such as places where the carriers can use a simple detour to avoid inspection), the network might not be very effective, and can even increase the damage caused by overweight trucks by increasing their travel distances (Franceschi *et al.*, 2020; Hooshmand & MirHassani, 2018; Marković *et al.*, 2015).

The issue of route evasion is one example of the kind of criteria that must be properly considered when placing WIM stations in a road network. Other important information for this decision is the volume of traffic over the network, existence of important origin or destination points such as cargo terminals, infrastructure availability, crash numbers, type of road geometry, pavement condition, amongst many other important criteria for this decision. Therefore, the process of placing WIM stations in a road network can be understood as a process of multi-criteria decision-making, in which the road planner seeks to make a well informed decision on the best locations for enforcement based on a variety of available relevant information and possible analyses (Ammarapala *et al.*, 2013).

In Brazil, a data-driven decision support system was developed for this process, in which data for a selection of relevant variables is collected and a reference weight enforcement viability index (in Portuguese: *Índice de Viabilidade de Fiscalização de Peso*, IVFP) is calculated for each road segment, in order to provide a base for comparison and prioritization between different possible location candidates. The resulting values are shown to the system planner in a custom-made geographic information system (GIS) so that the decision is made while seeing the road system as a whole and considering other geographical criteria that might not have been thought of in the first place. Besides providing relevant information, the system that was created also provides the planner with a numerical value that can then be used to readily prioritize between segments and also to justify the choice of high-priority segments.

This paper summarizes the Brazilian approach to the WIM placement problem by describing the process that is used by the Brazilian National Land Infrastructure Department (in Portuguese: *Departamento Nacional de Infraestrutura de Transportes*, DNIT). The aim of this paper is to help advance the academic discussion on this subject and provide a starting point for other entities that might presently be facing the same problem.

2. MULTI-CRITERIA DECISION SUPPORT METHOD

To aid in the WIM placement decision for the Brazilian road network system, a list of relevant criteria was firstly identified. Appropriate data sources for each of the relevant criteria were selected, and a reference database was established to create normalization functions. The normalization functions are a set of equations (one for each considered criteria) that transform the collected data into a normalized value that ranges between zero and two. These relations were proposed by the research team for the Brazilian case, and they express the growth in weight enforcement necessity as a function of the reference value. For instance, the higher the number of trucks that pass through a certain segment is, the stronger is the necessity for weight enforcement there, although this relation might not be linear.

A set of normalized values is then obtained for each road segment. Then, an equivalent set of weight parameters is informed by the analyst, and a weighted sum is calculated, which results in the reference IVFP value. The informed weight parameters allow the road planner to configure the method according to their wishes, by informing the relative importance of each of the criteria for the current analysis, and also to inform if a variable must have a positive or negative influence on the final IVFP value. This process is summarized in Figure 1.

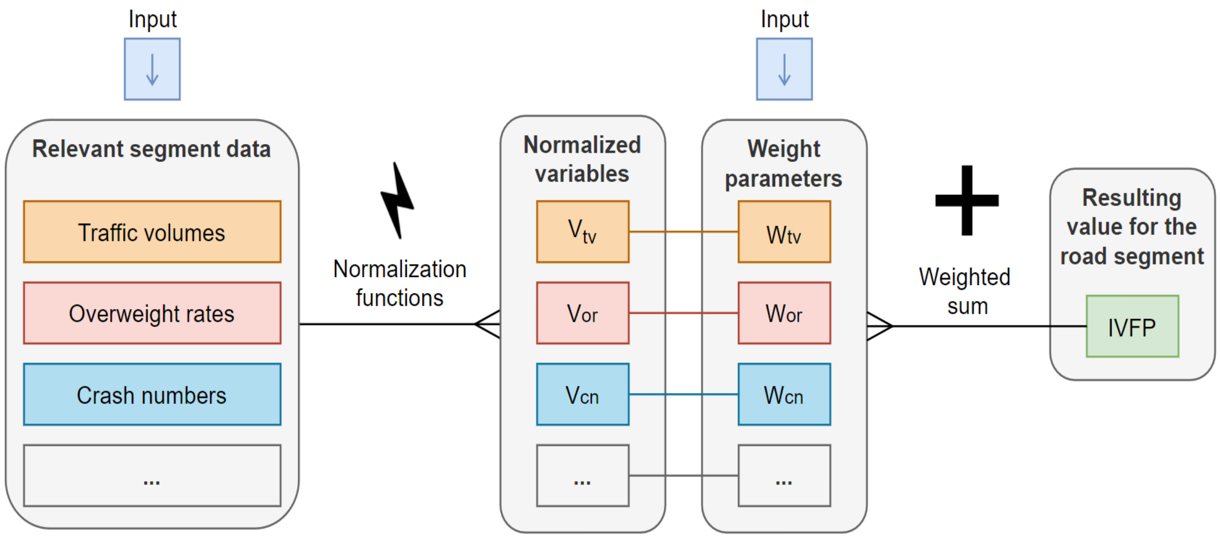

Figure 1: Multi-criteria decision method developed for the Brazilian case

As a result of the proposed method, for each of the road segments that compose the network, the IVFP value is calculated for the segment. This value is then used by system planners to aid in decision-making, in a flexible manner, that they find that most fit their current needs. For example, a common approach is to consider only the segments with a minimum IVFP value, and then analyze them in more depth by other means, such as obtaining more detailed information only for the selected segments. Another good use of the IVFP value is to promptly discard from the analysis those segments that, for any reason, cannot be used for weight enforcement, such as places where there is any administrative restriction for the planner's entity.

3. SIALOC - SPATIAL DECISION SUPPORT SYSTEM

The process described in Figure 1 is put into practice in Brazil by a Spatial Decision Support System (SDSS) called "Sialoc" (in Portuguese: *Sistema de Apoio à Localização de Postos de Pesagem*), which is developed by a research team at *Universidade Federal de Santa Catarina* (UFSC) and used by the technicians at DNIT. The system includes a packaged spatial database that integrates all the reference geographical data and which also performs the calculations needed to obtain the IVFP. The packaged database then serves geographical layers which contain the federal road segments in Brazil along with their resulting value for the IVFP. The open-source QGIS geographical information software is then used to build a custom GIS software that uses the spatial data provided in an interactive map. Besides the resulting IVFP value per segment, the system also provides all the reference data to be viewed by the analyst, along with settings windows through which the weights for the IVFP can be informed by the user. The specific tools that are used for this application are the PostgreSQL database tool with the PostGIS plugin, the programming language Python with the development libraries by QGIS (PyQGIS), and the PyQt platform for software interface. Figure 2 shows a screen capture of the Sialoc SDSS.

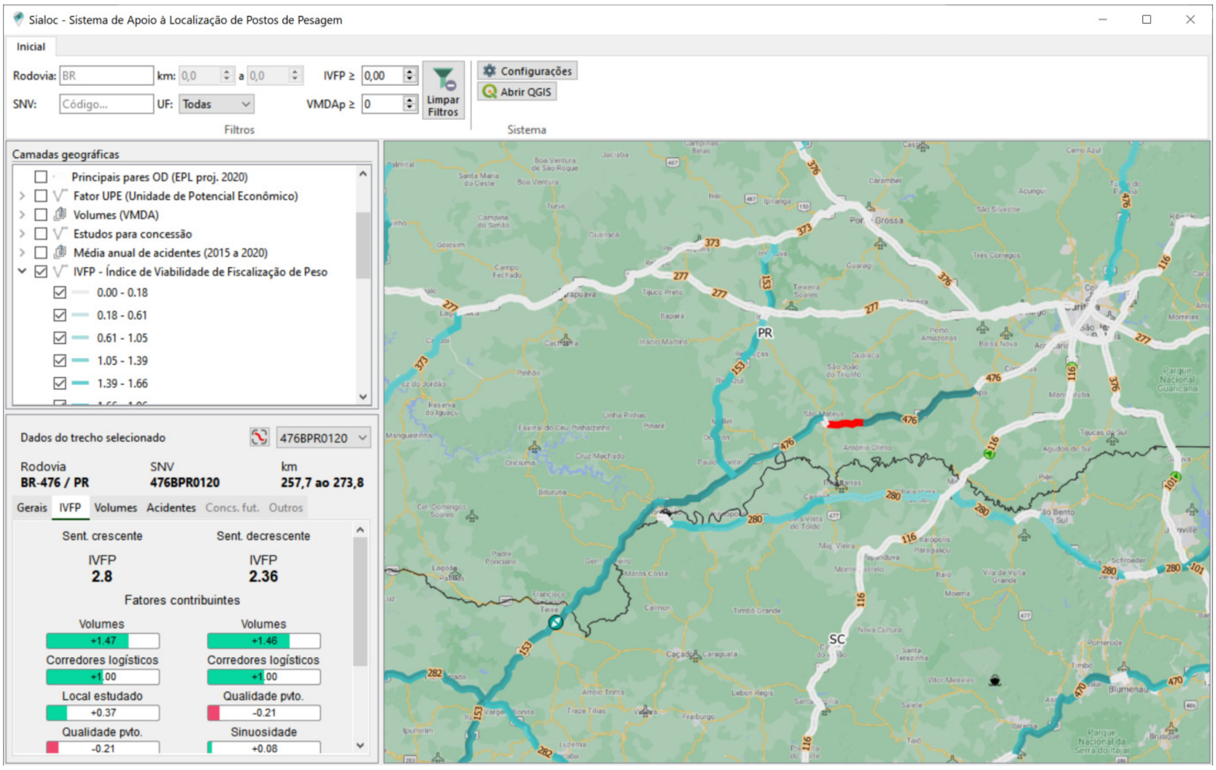

Figure 2: Screen capture of the Sialoc SDSS

4. WORKFLOW FOR WIM LOCATION WITH THE SIALOC SDSS

With the proposed decision support method via the IVFP reference index and the developed SDSS, the Brazilian road planners are able to make a supported decision on where to install WIM systems. They might use the developed tools in any way that they find best suits them for their current demands, as the system does not limit its use to a certain workflow. Nonetheless, the software has recently been used in Brazil to select locations for future mixed weight enforcement stations (where HS-WIM is used for preselection and a mobile low-speed scale is used for enforcement), which are currently in the planning process for installation in the next years. In this process, that the research team for the Sialoc software also participated in, a workflow was observed that might be useful as a proposal for application in other contexts (Figure 3).

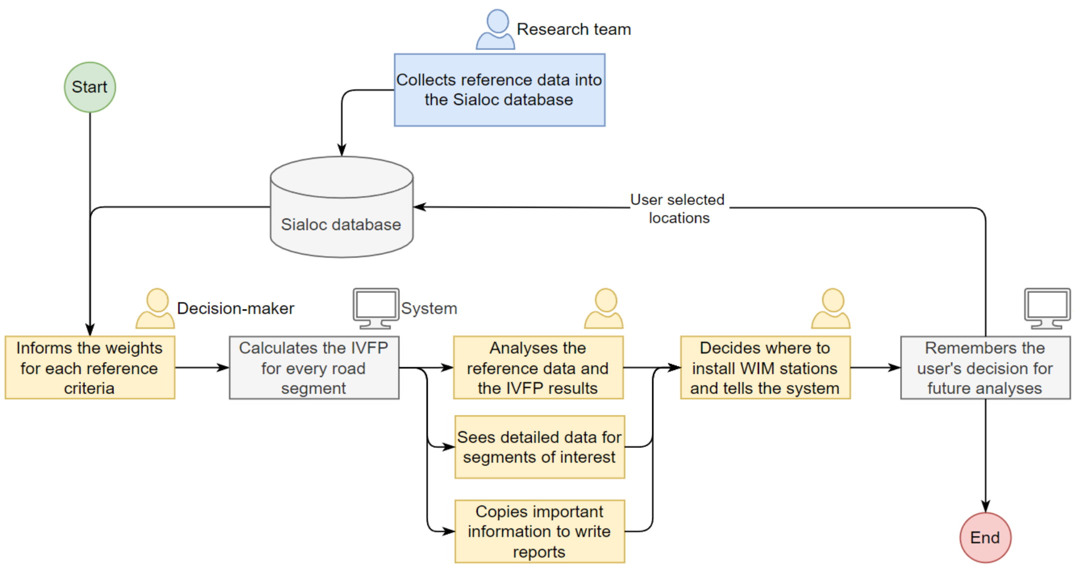

Figure 3: Example of a workflow for WIM location decision using the Sialoc SDSS

In this workflow, the research team participated actively by obtaining the reference data and integrating it into the software database. The software was then distributed with all data and spatial visualizations ready for use, and the decision-maker in the road planning entity is able to view all the relevant data and the calculated index in an interactive map, as shown in Figure 2. As an output, the final selected locations for WIM stations are then fed into the database so that it may be considered in future studies.

5. CONCLUSION

The Brazilian decision-support method for WIM station placement is currently in use by the federal department responsible for public highways (DNIT) to plan for the future weight enforcement activities and their locations. When creating this method, the main philosophy was that the decision may not be taken away from the road planning entity, since there are many criteria that they may want to consider, and those criteria can also vary from one study to the next. Also, while an academic decision-support method deals with the technical criteria that makes one location better or worse for WIM than another, the planner’s decision frequently includes other important criteria such as budget limitations, distribution of stations between different states and regions amongst other aspects.

Nonetheless, the technical side of the decision is facilitated by summarizing a wide range of relevant information into a single index. The advantages of giving the planners such index is that they are now able to easily judge which places are more viable for weight enforcement in a certain network, and can focus their effort in some high priority locations. Furthermore, the calculated index can be used by the road planner to justify their decision to the public by showing that they have selected a segment with a high index and, therefore, it is a high priority segment for weight enforcement.

The goal of this paper was to present the international community with the method that is currently being used in Brazil to support the decision of WIM systems’ location. The proposed method can serve as a starting point to plan for the same decision in any other context, and it can be adjusted to correspond to any application. Moreover, the fact that this method is currently in use in a country such as Brazil, with a continental size and very large road systems, shows its applicability in real contexts.

6. REFERENCES

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