

PROPOSED ALTERNATIVE TO ASSIST CURRENT OVERLOAD OPERATIONS IN SOUTH AFRICA

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ABSTRACT

Efficient overload control is of utmost importance to protect the road infrastructure in any region. An investigation into the status quo of overload control in South Africa provided evidence of low efficiencies and many instances of systematic evasion of overload control regulations without effective enforcement. In this article, we analyse data to obtain empirical evidence of the level of inefficiencies and to identify the primary factors that affect overload behaviour and the efficiency of current enforcement measures. The data used consist of traffic flow, weigh-in-motion and static scale data over the period 2012 to 2015. We propose an improved overload control system based on more accurate monitoring of road user behaviour using a combination of technologies and the more intelligent use of available data, and discuss the legal implications of the proposed application and steps needed for a pilot deployment of the proposed system.

1. INTRODUCTION

Overload control is implemented throughout the world by roads agencies as part of general road management. These systems are implemented to minimize the damaging effect on the road caused by overloaded vehicles. The negative impact of overloaded vehicles is not limited to physical damage to the road surface, but have a large economic impact as well (Szary & Maher, 2009). The manner in which current overload control procedures are applied results in significant time delays, even for fully legal vehicles, but is viewed by the relevant roads agencies as essential to enforce legal driving weight limits of trucks (Hoffman, et al., 2013). These inefficiencies sometimes cause long queues at weigh stations resulting in trucks being ordered to bypass the weigh station; this effectively creates loopholes in the enforcement system (Kamyab, et al., 1998), (Lee & Chow, 2012). This bypassing to avoid delays could easily include overweight vehicles that will damage the road infrastructure. Freight vehicles may also deliberately choose to bypass weigh stations based on knowledge that the vehicle is overweight in order to avoid prosecution (Szary & Maher, 2009). In some cases it occurs that the drivers of overloaded trucks deviate from main routes to skip weigh stations all together by following secondary roads; this cause severe damage to such secondary roads, resulting in the deteriorating status of South Africa's general road infrastructure (Crickmay, 2010).

Overloading may increase the competitive edge of freight companies as it allows them to haul larger quantities of goods (de Pont, 2012). This overloading ensures higher productivity and utilisation of freight vehicles (Kienhofer, et al., 2013). Multiple industry approaches have been developed and implemented to reconcile productivity within logistics with overloading compliance and vehicle design. (de Saxe, et al., 2013), (Bosman & D'Angelo, 2011). A relevant example is the Road Transport Management System (RTMS), a South African initiative for self-regulation of road freight transporters that was initiated in the timber and sugar industries (Crickmay, 2010). These initiatives intend to lower illegal activities and increase the accuracy of overload control to minimize the large economic impact on the road infrastructure.

2. DEFICIENCIES IN EXISTING OVERLOAD CONTROL MEASURES

The current overload control system implemented in South Africa is characterised by lack of uniformity across different regions and lack of integration between different subsystems. The different variations of TCCs (traffic control centres) found on our national roads may consist of

- static scales,
- weigh-in-motion (WIM) scales inside the road surface,
- screener lanes forcing heavy vehicles to correctly travel over the WIM scale,
- cubicles providing traffic officials with alarms and photographic images of vehicles triggering the WIM scale,
- ANPR (automated number plate recognition) cameras that identify vehicles in all lanes based on registration number,
- piezo-electric vehicle counters that detect vehicle axle configurations,
- RFID (radio frequency identification) readers combined with RFID tags mounted on vehicle wind screens, and
- manual enforcement by traffic officials stationed at WIM and static scales.

The pros and cons of the most common TCC configurations in use are discussed below:

1. Static scales used in isolation: The primary disadvantage of this configuration is the fact that all heavy vehicles, whether legally or illegally loaded, are forced to visit the scale. This can lead to very long delays, typically at border posts during times of high congestion, disrupting the operations of fully compliant road users which is detrimental to the national economy.
2. Combined WIM and static scales: this allows vehicles to be screened before informed whether they must visit the static scale. Several disadvantages however still remain:
 - As WIM scales are less accurate than static scales, the threshold to direct vehicles to the static scale is normally set at 10% below the legal limit – legal vehicles that are loaded close to capacity (as is often the case) can still be repeatedly directed to a static scale during the same trip.

- Illegal vehicles can evade this system simply by not driving in the WIM lane or by ignoring the WIM signal. This is supposed to be prevented by the traffic official on duty, but practical observations have shown that in a large fraction of cases this does not happen.
3. Adding screener lane to WIM scales: this can help prevent heavy vehicles from either pretending that they were not aware of a WIM lane or driving in the WIM lane without properly driving over the WIM scale (i.e. keeping to the edge of the lane). If the WIM screener lane is ignored and no official is on duty such an offense will however go unnoticed.
 4. ANPR cameras: By adding ANPR cameras in all lanes at the position of the WIM it is possible to detect heavy vehicles in non-WIM lanes by linking their registration numbers to other information on the eNATIS system. This still leaves the loophole that if the vehicle carries an illegal number plate then the wrong vehicle owner may be implicated. It is known that the heavy vehicle industry suffers from a high incidence of illegal number plates.
 5. Adding RFID to the WIM scale: RFID provides the option of a much higher level of integrity of vehicle identification (Hoffman *et al*, 2013). The use of secure RFID tags either on the windscreen or number plate can ensure that vehicles are correctly identified and that the true vehicle owner is prosecuted. It however requires the deployment of RFID tags on the entire vehicle population which is not currently the case.

From the above it can be seen that all system configurations currently used in practice suffer from specific limitations and deficiencies. The combined use of a WIM scale with screener lane and ANPR camera to verify the potential non-compliance and identity of a vehicle, followed by a static scale for enforcement is currently the most effective configuration being used.

3. THE ROLE OF LAW ENFORCEMENT

A common factor applicable to all TCC scenarios is the dependence on some form of manual supervision and enforcement by officials. A weakness inherent to the status quo is that the parties that financially suffer from overload offenses (roads agencies and toll road operators) do not have direct control over the enforcement agencies (local traffic authorities). Based on discussions with a representative set of industry players this appears to be the single biggest contributor to current deficiencies in the overall system, as the following types of behaviour is commonly observed within the overload control enforcement process:

1. Traffic officials stationed at WIM cubicles often experience difficulty to correctly identify the relevant heavy vehicle that has triggered the WIM scale, resulting in the wrong vehicles being diverted to the static scale.

2. The traffic official on duty often has the intention to reach his/her daily quota for number of heavy vehicles weighed as quickly as possible, and hence indiscriminately directs all heavy vehicles on the road towards the static scale. Once the prescribed quota has been reached the official will go off duty, allowing all vehicle to pass the static scale.
3. A vehicle is directed to the static scale, weighed, found to be overloaded, directed to the designated area and fined. In such an instance, the driver is supposed to request a relief vehicle to collect the excess weight before the journey can commence. A bribe is however paid to the traffic official and the weigh master who overrides the internal control system and the vehicle is allowed back onto the road with its illegal load.
4. An illegally loaded vehicle triggers a WIM scale but ignores the signal and passes the static scale. A notification is sent to a central control office from where a traffic official is dispatched to pull off and impound the vehicle. A bribe is subsequently paid and the vehicle is allowed back onto the road with no traceability or records of these events.

In all of the cases above there are currently no records of what actions were taken by traffic officials based on specific information that was provided to them. There is furthermore no traceability of the actions of vehicles found to be illegally loaded, and whether subsequent detections of these vehicles indicate that their illegal loading status was in fact corrected. There is also no formal record of systematic law evasion and/or overloading by specific fleets of vehicles, even though there is awareness of the serious nature of these offenses and of the fact that information is available within the system to identify and act against such players.

4. VERIFICATION OF THE NATURE OF CURRENT OVERLOAD BEHAVIOUR

Our discussion so far provides proof that the current overload situation results from a variety of underlying causes:

- Economic incentives to road users to offend and a lack of incentives to comply, resulting in high levels of overloading and evasion of the control system;
- Limitations within existing technology systems to correctly monitor and control overloading behavior;
- Opportunities that exist for enforcement officials towards self-enrichment by selectively acting against offenders without being caught out.

Before an improved overload control concept can be proposed it is important to verify the extent to which the above factors are indeed present in practice. The need also exists to verify which are the dominant underlying causes for consistent overloading; this would assist efforts towards the design of a more effective control system.

In order to study these issues, we collected and analysed historical data available from existing overload control and traffic monitoring systems. Our analysis was aimed at characterizing

- the behavior of road users during different times of day when different levels of physical law enforcement could be expected to be present, as well as

- the performance of existing overload control systems, including enforcement officials.

The data that was used represents the movement of vehicles along South Africa’s busiest internal corridor (Durban to Johannesburg) as well as on South Africa’s busiest corridor to neighbouring countries (Johannesburg to Beitbridge).

5. DISCUSSION OF RESULTS

The main results are displayed in figures 1 to 4 below. Figure 1 indicates that the pattern of vehicle movements as function of time of day is quite different for heavy vehicles than for all vehicles: during the middle of the day heavy vehicles represent only about 10% of the total count, going up to between 40 and 80 % before 7 am and after 7 pm.

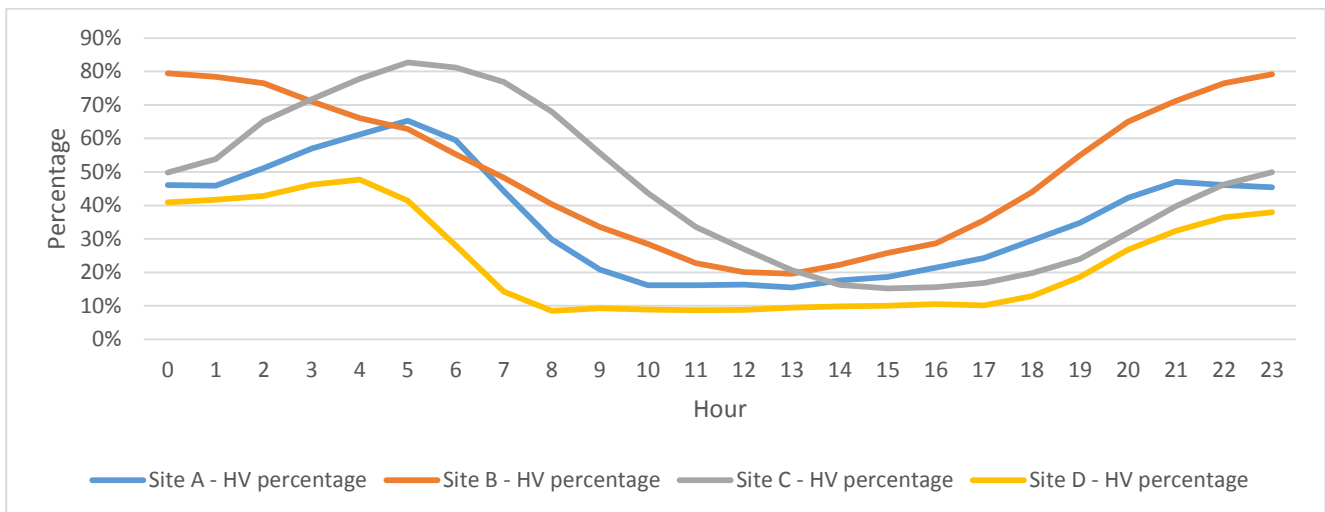


Figure 1 Heavy vehicle count as fraction of total vehicle count as function of hour of day for different monitoring stations

Figure 2 indicates overload statistics for eight weigh-in-motion monitoring sites on the corridor from Durban to Beitbridge. The vehicles were weighed over a three-year period; 78% to 82% of total traffic was weighed and only 7% to 9% of these vehicles are stated as overloaded. A total of 19.7 million vehicles weighed during the three-year period were not overloaded. If all of these vehicles were forced to repeatedly visit all static scales on any given trip a huge amount of time would have been wasted, providing a clear argument against the use of static scales in isolation. The WIM scale information interpreted in isolation does however not provide a clear indication of the efficiency of TCC configurations that combine a WIM scale with a static scale. For that purpose, we also need to also study static scale data.

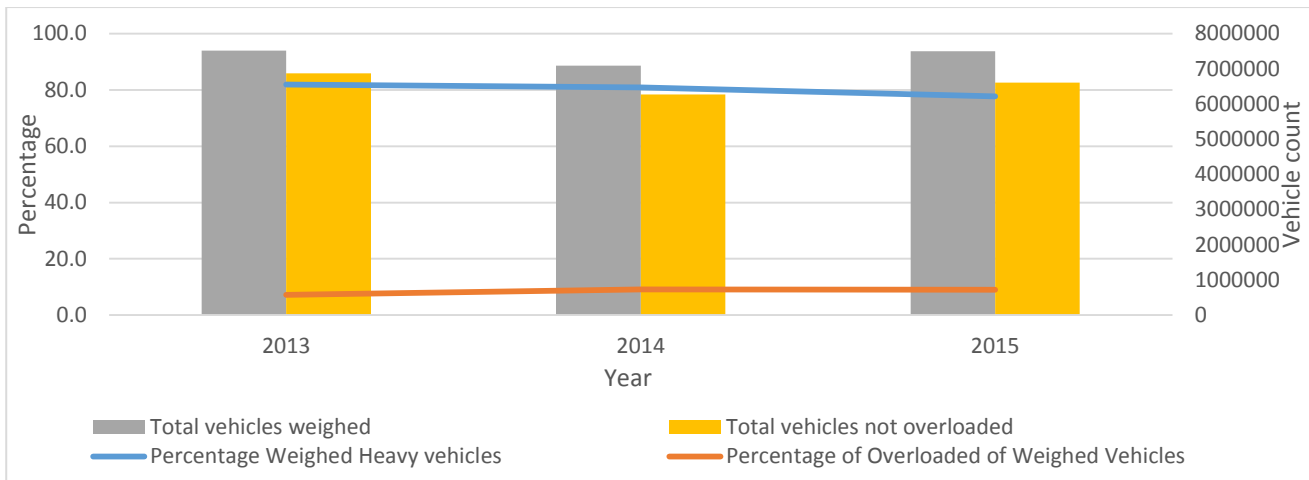


Figure 2 Average overload statistics from weigh-in-motion sites for 2013 to 2015

Currently installed TCCs that include both a WIM and a static scale does not have a reliable method to verify if a specific vehicle that triggered the WIM scale was in fact seen at the static scale; similarly there is no reliable measurement to indicate whether a vehicle that is statically weighed did trigger the WIM scale. The accuracy of current schemes used to direct heavy vehicles to static scales can however be quantified to some extent by studying the weight statistics of vehicles that are statically weighed. If the installed systems are functioning correctly (i.e. WIM scales correctly trigger vehicles that are within 10% from the legal limit) and operational procedures are correctly implemented by traffic officials, then the vast majority of statically weighed vehicles should be above a level set at 10% below the legal limit. Vehicles weighing in at below this threshold should not have ended up at the static scale, as WIM scales are in general more accurate than the allowed 10% tolerance; such vehicles were directed to the static scale due to the incorrect functioning of some element of system operation.

Against this background we analysed the statistics of vehicles weighed at static scales that are preceded by a WIM scale that triggers vehicles within 10% of the legal threshold and then directs them to the static scale. Figure 3 displays the fraction of vehicles, visiting such static scales, of which the static weight was more than 10% below the legal threshold. This fraction of vehicles, which varies around 60% of all weighed vehicles, could not reasonably have triggered the preceding WIM scale. Based on the available evidence it can thus be argued that only around 40% of vehicles at the static scale should have been directed there as the remaining 60% of the vehicles never triggered the preceding WIM scale. It is unlikely that vehicles not triggering the WIM would have voluntarily visited the static scale; the reasonable conclusion is that this 60% of vehicles visiting static scales were incorrectly directed to the static scale by traffic officials, either by mistake or deliberately to make up the daily quota. This data provides clear and tangible evidence of the general observations described in sections 2 and 3 regarding the inaccuracies inherent to the current system.

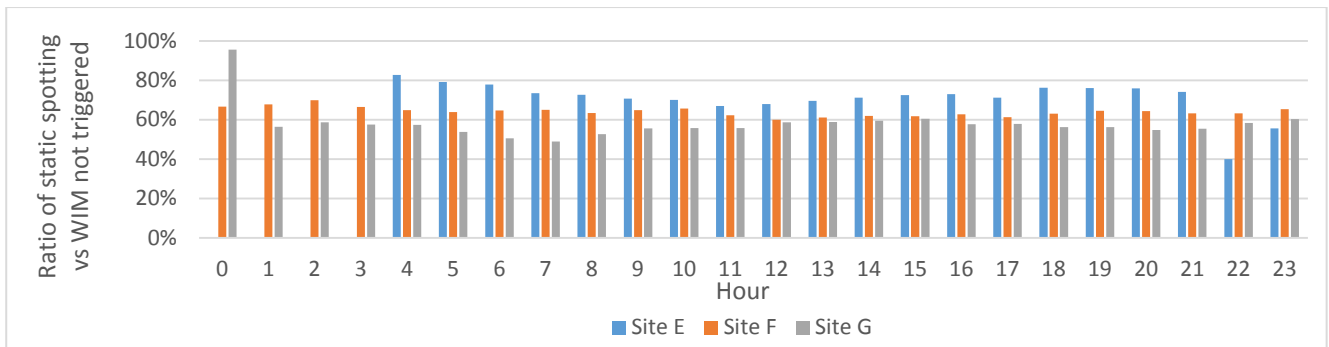


Figure 3: Fraction of vehicles visiting the static scale that could have triggered the WIM scale, for different sites and as function of hour of day

While figure 3 provides evidence of the inefficiency of the current system to correctly direct vehicles to the static scale, it does not address the issue of the potential unnecessary repeated static weighing of those vehicles that are correctly directed from WIM to static scale. As described in section 2 above, a vehicle that is legally loaded but that is within 10% of the legal limit will trigger the WIM scale and should, according to current procedures, be directed to the static scale. If it passes several TCCs along the same corridor it will be repeatedly pulled off, as the different TCCs are not linked and are therefore not aware of the outcome of a static measurement at a preceding TCC.

In order to determine the fraction of vehicles that falls within this category we performed the following calculations:

- Firstly the vehicles that, based on their static weights, could have triggered the preceding WIM are identified and counted;
- Secondly the overloaded vehicles at the same static scales are identified and counted;
- The overloaded vehicles are then expressed as a fraction of vehicles that triggered the WIM scale.

Figure 4 shows the percentage of all the vehicles that triggered the WIM (based on their static weights) and that were actually overloaded. This figure is around 10% for most of the day. The implication is that around 90% of vehicles that triggered the WIM (and that were correctly directed to the static scale according to current procedure) were in fact not overloaded. A vehicle falling into this category and following a corridor with multiple TCCs would therefore be repeatedly pulled off to static scales even though it was legally loaded; on the route from Durban to Beitbridge this could happen 6 to 8 times. If however the different TCCs were linked and could respond intelligently to data received from other TCCs on the same corridor then most of these unnecessary static scale visits could have been eliminated.

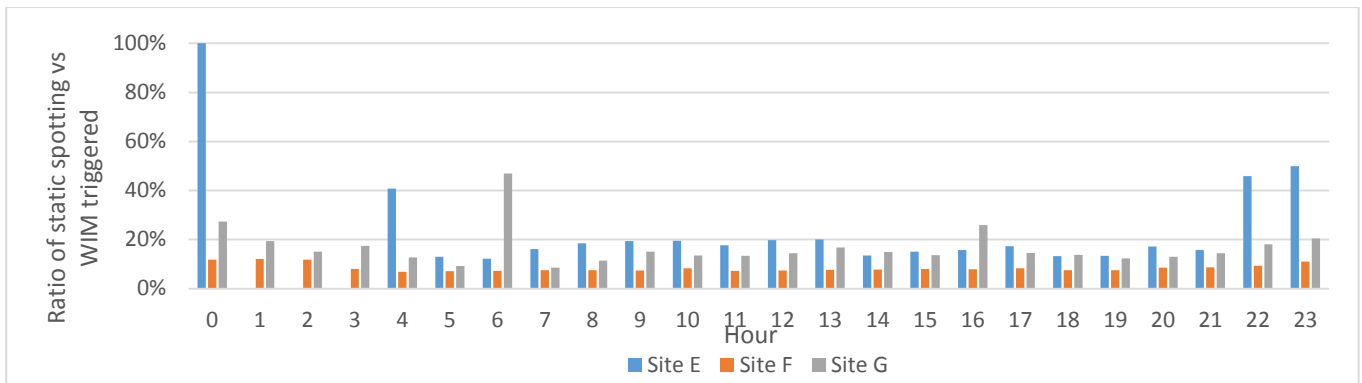


Figure 4: Fraction of heavy vehicles visiting the static scale after triggering the WIM scale that were actually overloaded, for different sites and as function of hour of day

We can summarise our findings as follows:

1. Heavy vehicles tend to travel mainly during after hour periods when there tend to be a low presence of traffic officials around TCCs (Figure 1).
2. On average less than 9% of vehicles weighed by WIM scales are overloaded (Figure 2).
3. Of all vehicles directed to static scales based on current procedures only 30 to 40 % should have been statically weighed, based on the outcome of their actual static weights (Figure 3).
4. Of all vehicles that were supposed to be directed to the static scale only around 10% are actually overloaded. This means that only around 3-4% of all vehicles visiting the static scale are overloaded (Figure 4).
5. Most of these unnecessary static scale visits can be eliminated should different TCCs on the same corridor be interlinked; this will have a significant beneficial economic impact on the operations of road transport operators and can also reduce wear and tear on TCC infrastructure (Hoffman, 2014).

6. INCENTIVISING ROAD USERS TO BECOME COMPLIANT

From the above results, it is clear that the current approach to overload control as applied on South Africa's primary freight corridors is largely ineffective: it does not deter road users with a tendency towards breaking the law for financial gain, while it penalizes compliant road users who load their vehicles effectively and strictly keep to overload procedures. On the other hand, the current system offers few benefits to compliant road users to obey the law, especially as they directly compete against offenders who are improving their profit margins based on overloading.

The RTMS was a first effort towards creating a system of self-regulation that allows compliant road users to make their vehicles identifiable in exchange for preferential treatment. This system proved to be very effective within specific industries where the supply chain principals effectively enforced the rules of the system and created clear obstacles for offenders (Crickmay, 2010). Our results however show that the

system has been much less effective for the road freight industry in general where the control system is operated by roads agencies and depends on enforcement by traffic authorities.

Based on our own observations and discussions with many participants in this industry our conclusion is that a more effective system will have to provide tangible benefits for compliant road users, implement more severe penalties for offenders and provide traceability of efforts towards enforcement. In order to achieve this an improved system is required that can clearly differentiate between compliant and non-compliant road users; this must involve a much higher level of automation that eliminates the human element from critical steps in the process. This is applicable both regarding the benefits created for compliant road users as well as enforcement actions against offenders. The next section describes a proposed system that could achieve at least a significant improvement upon the status quo.

7. PROPOSED IMPROVED OVERLOAD CONTROL SYSTEM

Existing telemetry technology can support a total redesign of the existing overload control concept. Taking into account the to be expected resistance against change in any system involving a large number of stakeholders, we propose that a new system is deployed in two phases: Phase 1 will improve the efficiency of existing elements of the current system, while Phase 2 will add new elements that will drastically change the philosophy behind the system.

For Phase 1 the following changes are proposed:

1. It must provide for an extended system of certification of compliant heavy vehicle operators, using the RTMS as point of departure, and requiring certified vehicles to carry a secured RFID tag. Untagged vehicles must be tagged when visiting static scales.
2. All static scales must be complemented by upstream WIM scales that are equipped with screener lanes, RFID readers for high-integrity identification of certified vehicles and ANPR cameras on all non-WIM lanes to detect heavy vehicles that do not use the WIM lane.
3. Different WIM scales must be connected in real time and provided with a sufficient level of intelligence to prevent legally loaded vehicles that are close to the threshold from being repeatedly directed to the static scale. This will create a clear incentive for legal operators that accurately load their vehicles to comply with system requirements.
4. Instructions provided by WIM scales to potentially overloaded vehicles must be automatically enforced by a system of booms that direct heavy vehicles from the screener lane either to the static scale or back to the main road. This will eliminate the ineffective directing of vehicles by traffic officials who are not held accountable for their actions.

5. Vehicles operated by uncertified road users (that do not carry registered RFID tags) will be regarded as representing a higher risk and will be subjected to stricter enforcement measures (e.g. using lower triggering thresholds at the WIM scale) and higher tolling fees.
6. Should any heavy vehicle evade the WIM lane an ANPR camera will detect its registration number, allowing the vehicle to be identified and linked to its legal owner using eNATIS.
7. Should an uncertified vehicle use illegal number plates and evade the WIM lane, its illegal status can be manually verified by comparing the corresponding camera image with eNATIS data linked to the same registration number. If a vehicle carrying illegal number plates is spotted, a task force will have to be dispatched to intercept it while still *en route*, impound it and identify the owner. Successful enforcement against such vehicles will obviously require a high level of integrity from this task force, or else it will fall victim to the same weaknesses of the existing system.
8. By using the above elements of monitoring and control, it will be possible to build up a long term track record of overload behavior for all major road users. Even if the odd vehicle manages to evade the system, the major system objectives will be achieved, as there will be effective action against large road users who systematically overload and evade enforcement. At the same time the compliant behavior of certified users will allow them to qualify for preferential treatment, not only in terms of reduced frequency of static scale visits but also in terms of differentiated tolling fees.

For Phase 2 the following elements are proposed to be added:

1. The internal scales of certified road operators must be regularly calibrated and linked to the centralized overload control system; if such internal load measurements are accepted by the roads agency as sufficient proof of the loading status of a vehicle upon departure then almost all static scale visits by certified vehicles can be eliminated.
2. The existing GPS tracking systems of certified operators must be linked to the centralized system to provide summary data to the roads agency about the movements of the vehicle as from the time when it was internally weighed until it reaches its final destination.
3. A system must exist to allow certified operators to submit electronic declarations to the centralized system before a vehicle is dispatched, in the process informing the roads authority about the intended route, the origin and destination, the nature of the load and the overload control stations to be passed along the way. This will allow the system to process the GPS tracking information about such vehicles in real time to determine if the vehicle displayed any kind of behavior that could represent an overloading risk (e.g. stopping for a sufficient period along the way to allow cargo to be added).

4. When the GPS system of a tagged certified vehicle indicates that it is passing a TCC the system will automatically verify if it was correctly observed by an ANPR camera as well as by an RFID reader, if it followed the correct lane and if the WIM scale measurement can be reconciled with its originally submitted weight. This will allow the system to optimally handle such vehicles in real time as it passes through control stations.
5. Should all of the above elements of the proposed system be in place, it can be used to implement a compulsory GPS based electronic tolling system for heavy vehicles. This will discourage non-compliant road users from evading high tolling fees by taking secondary roads around tolling stations; as such behavior will be detected and will further increase their tolling rates.

Non-compliant transport operators can be expected to attempt efforts towards sabotaging a system of this kind, e.g. by damaging RFID tags or switching off tracking devices when TCCs are evaded. Continuous collection of fleet behaviour will however easily detect such patterns of behaviour; this can be used to automatically downgrade the status of such operators, enforcing the highest level of tolling fees onto them or even suspending their business licenses.

8. CONCLUSIONS AND RECOMMENDATIONS

The existing overload control system as employed on South Africa's road network has been demonstrated to be deficient in many respects. This results from non-uniform system configurations at different TCCs, many of these leaving serious loopholes for offenders, lack of integration between different data sets reflecting various aspects of overload behaviour, critical dependence on enforcement by a fragmented set of traffic authorities, and lacking control over the accuracy and integrity of these enforcement agencies.

The proposed alternative will be based on a more uniform design of control infrastructure, integration of data from different sources, including systems operated by fleet owners, a system of incentives to compliant road users, and on-going real time system supervision based on real time data collection. The proposed system must have the necessary built-in logic to correctly interpret combined data sets originating from different sources allowing correct diagnostic decisions and enabling real time enforcement. Such enforcement must be automated as far as practically possible, but will also require a dedicated task force whose actions will have to be closely monitored to ensure a high level of integrity, in contrast to the status quo.

Future work will involve the analysis of field data from a larger number of TCCs representing all identified overload system configurations to accurately determine the extent to which current overload behaviour from road users is influenced by system design. A simulator is in the process of being developed to allow the simulation of different system designs and to measure its impact on time delays experienced by road users as well as the impact of incentives and penalties on the behaviour of truck drivers and enforcement officials. A prototype system is in the process of being deployed along a portion of the N3 and N1 North-South corridors to demonstrate the

beneficial impact that the addition of RFID and the sharing of information between different TCCs can have on overall system performance. A financial impact study will also be conducted for multiple stakeholders using the corridor.

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