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Enhancing Customs Risks Management System with GPS Data: A Simulation Approach

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Abstract: Numerous calls have been made for Africa to improve the efficiency of her trade corridors. The calls have been predicated on a number of reasons including an understanding that in this modern and globalised world, an efficient trade corridor promotes economic competitiveness of a country or region. Delays associated with customs processes, especially with cross-border trade has been singled out as one of the major sources of long delays, hence, the decrease in the efficiency of Africa's trade corridors. The aim of the simulation-based study in this study was to investigate the possible impact of using GPS-based data on efficiency of custom's cargo risk assessment, management and control. The simulation of using real-time GPS-based monitoring data was combined with a posteriori controls. The results show that, infraction detection improvement of at least 27.45% is possible when only 14.9% of cargo is intrusively inspected compared to intrusively inspecting 20.6% of cargo when using a posteriori procedures as proposed in some published articles. The results show that, using a posteriori risk assessment procedure together with GPS-based real-time cargo trucks monitoring data and other technologies such as RFID systems can significantly improve the efficiency of customs processes including infraction detection.

INTRODUCTION

There is a view that, there is a close link between the rate of growth of the economy of a country or region and the level of efficiency of its trade corridors or logistics, (Laksmanan and Anderson, 2002; Havenga *et al*., 2014; Alises and Vassallo, 2016). The logistics referred to encompasses both the domestic as well as international movement of goods. International movement of goods (cross border operations/logistics) is well known to be one of the sources for logistics inefficiencies in developing countries (Barka, 2012). The aim of the research described in this study was to investigate cross border operations in Africa in order to find possible ways of improving the efficiency and other incidental benefits to African economies.

The long delays and lack of efficiency observed within African cross border logistics is mostly attributed to delays experienced at border posts. Unlike developed nations, Africa has been slow in adopting the Revised

Kyoto Convention (RKC) which recommends limiting custom's intrusive inspections of cargo and instead use non-intrusive inspections (De Wulf and Sokol, 2004; Buyonge and Kireeva, 2008; Laporte, 2011). Buyonge and Kireeva (2008), attribute the wide spread intrusive inspections to multiple factors including; the lack of trust between business and custom's entities, lack of sufficient supportive state infrastructure, several different inspection agencies at the border posts and wide-spread corruption perpetrated by some trade corridor participants including customs officials. The other reason why there is still so much intrusive inspections in Africa is the use of the so-called Automated System for Customs Data (ASYCUDA) of which the early version was a closed system that did not allow its modification. ASYCUDA is still being used in some countries. This meant that various customs authorities could not modify it in order to improve their risk assessment and management procedures. The early version of ASYCUDA was limited to a procedure of using a set of selected criteria in deciding the cargo/goods to be intrusively inspected. The criteria included; a list of importers/exporters, the origin of goods/cargo, the tax applicable to the goods and so forth (Laporte, 2011). The other obvious reason why intrusive inspections are still widespread in Africa is that the revenue derived from customs duty/tax represents a significant source of government income.

Problem statement: As stated by Buyonge and Kireeva (2008), if Africa is going to realise a faster economic growth and become competitive at global level, it needs to significantly reduce the cost of trade transactions along with other appropriate economic measures. The factors driving high costs of trade transactions in Africa include the long delays in processing cross border cargo at border posts. These delays are mostly attributed to customs processes, hence, the urgent need for custom's reforms and other initiatives to promote competitive trade in Africa. As stated in previous paragraphs, numerous African countries need the income derived from customs tax and duties, hence, the intrusive inspections at border posts. The problem faced by African countries is therefore, a dire and urgent need to find a balance among three somewhat contrasting objectives; the need to generate enough income from custom duties/tax, the need to minimise intrusive inspections at the border post and the overall objective of facilitating competitive trade in Africa.

This study describes a proposition in which GPS tracking data is used alongside a posteriori procedure with the object of improving the efficiency of customs risk management and controls at border posts. The aim of the research was two-fold; to find ways of minimising intrusive inspections at border posts using GPS tracking data together with a posteriori procedure and maintaining or improving levels of income derived from customs tax/duties. Upon successful implementation of the proposed improvements, the developing nations, particularly Africa will inevitably take an important step towards full participation in the fast emerging business phenomenon, the so-called global value chains (Deborah and Low, 2013; UNIDO., 2015).

Literature review: Laporte's work (Laporte, 2011) is of great importance to the work described in this study. In agreeing with the WTO (World Trade Organisation) as well as the revised kyoto convention recommendations about the need for minimising custom's intrusive inspections, Laporte stressed the urgent need for governments to start relying more on data communication as well as risk estimation tools at all essential levels of the customs chain. In particular, stressed a need for the implementation of a posteriori inspection tools.

Laporte proposed a score-based approach on using a posteriori inspection and thereafter apply appropriate statistical methods for score computing. Laporte's results showed that, when a posteriori risk profiling procedure was applied, only 20.6% of the total customs declarations needed to be inspected in order to capture 96.6% of the declarations with infractions. These findings suggest that, developing countries can manage to continue collecting substantial revenue through tax/duty collection without much intrusive inspections if they adopted a posteriori procedure. However, in this study, it is recommended that a posteriori risk-profiling procedures should be used alongside real time monitoring techniques such GPS tracking data, RFID (Radio Frequency Identification) system and so forth.

The new proposed system described in this study has the so-called CREMS (Customs Risk Engine and Management System) at the core of the system. The role of CREMS is summarised in Fig. 1 and further described in detail in subsequent paragraphs. The focus of this study was to investigate, through simulations how a combined used of a posteriori procedures together with real-time monitoring of cargo in transit as assisted by CREMS can improve infraction detection at border posts.

MATERIALS AND METHODS

Description of the new proposed system: Hoffman *et al*. (2015), proposed the idea of CREMS as the central system in all the transactions of the envisaged improved integrated cross-border logistics. When compared to the current systems, CREMS will include a more enhanced risk engine module that uses a posteriori procedure together with real-time GPS cargo tracking data. It will also incorporate monitoring and controlling functionalities as summarised in Fig. 1. The monitoring and controlling functionality will be enabled by GPS as well as by an assortment of auto-ID systems led by RFID (Radio Frequency Identification) system (Hoffman *et al*., 2013). CREMS will monitor the cargo in transit, the conduct of

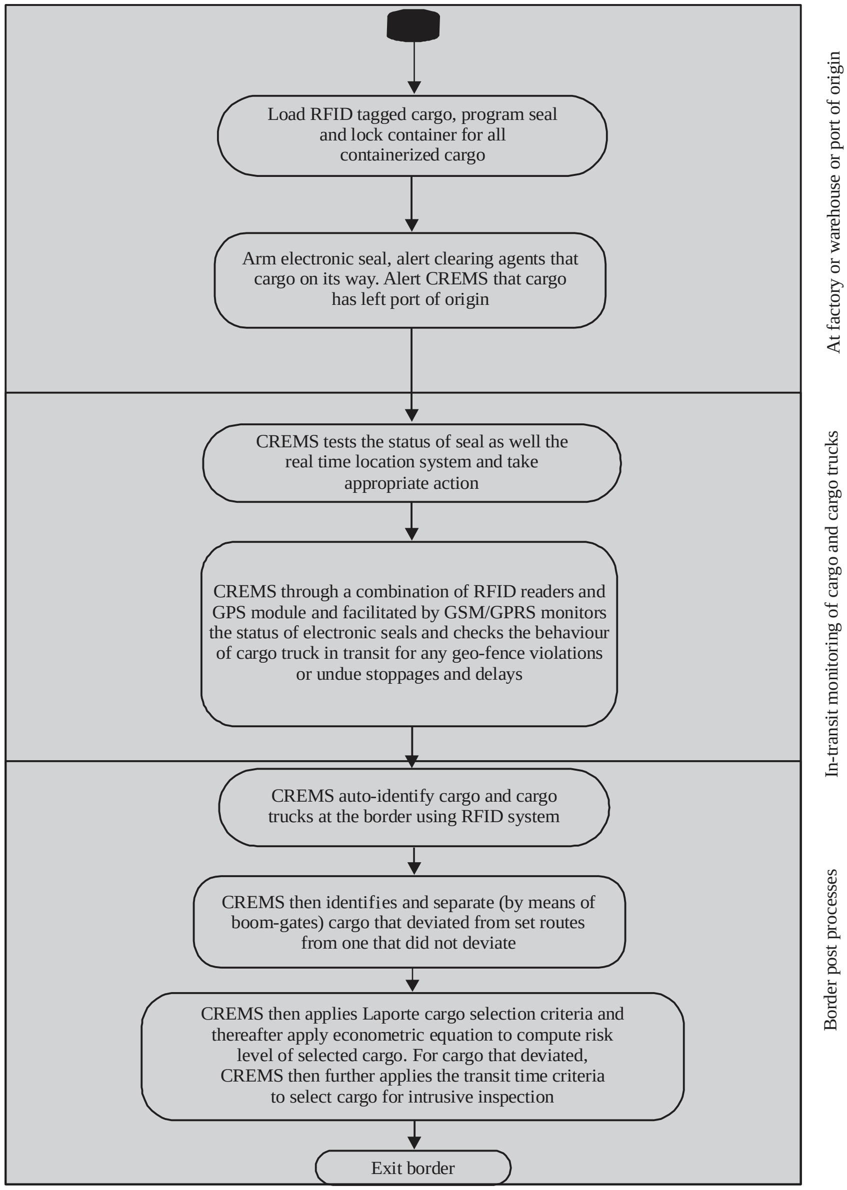

Fig. 1: Summarised process flows for cargo in the new proposed system

custom's officials at border posts and that of truck drivers as they traverse from ports of origin to the border posts. Figure 1 summarises the processes that cargo goes through before departing from their respective ports of origin as cargo traverse from the ports of origin to the respective border posts and the processes upon arrival at the border post in the new proposed system.

Figure 2 shows in detail the risk assessment procedure which is an expansion of the brief description given in Fig. 1. The risk assessment flow chart applies to cargo on arrival at a border post. On arrival at a border post, cargo is sorted according to whether the cargo ever deviated from the set routes as determined from GPS tracking data or whether it did not deviate at all. The cargo that would have deviated from geo-fenced or set routes is considered to be High Infraction Risk (HIR) cargo while Low Infraction Risk (LIR) cargo is the cargo that would not have deviated from set routes but has taken longer than the upper transit time threshold for a given route. The cargo that does did not deviate and arrives with the norm transit time for a given route is normally considered to be No Infraction (NI) cargo in the absence of frequent prior infractions determinable from econometric Eq. 1. The HIR and LIR cargo are subjected to further detailed assessment based on a combination of Laporte's a posteriori risk assessment procedure together

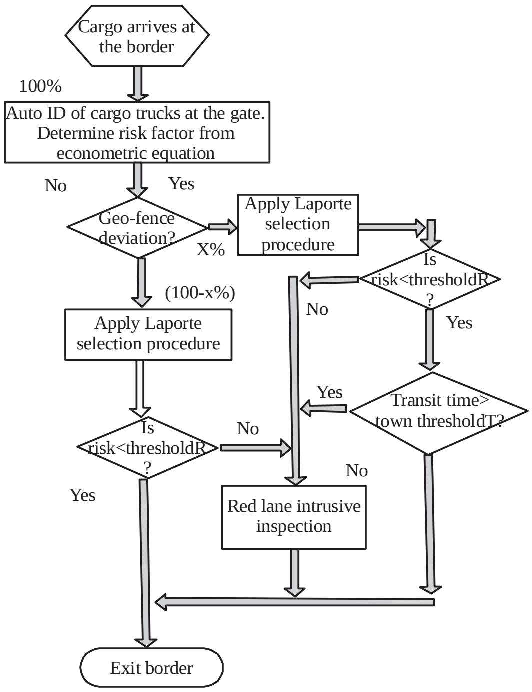

Fig. 2: Risk assessment flow chart

with cargo transit time as compared to the known average transit time to traverse from their respective towns or ports of origin. These two assessment procedures are summarised in Fig. 2 in the decision blocks showing cargo that would have deviated from their geo-fenced or set routes.

In the proposed system, the econometric Eq. 1 is used in computing the risk associated with each new declaration. This equation was adapted from the econometric equation used in Laporte's article but with a new proposed GPS parameter as shown:

$$\Pr(\text{Inf.}) = \alpha+\beta_1 fq_{\_\text{criteria }1_{ij}}+\beta_2 fq_{\_\text{criteria }2_{ij}}+ \beta_3 fq_{\_\text{criteria GPS}}+, ..., \beta_N fq_{\_\text{criteria}N_{ij}}+\varepsilon_{ij} \quad (1)$$

The term $\beta_3 fq_{\_criteriaGPS}$ represents the infringements of geo-fenced or set routes as determined from GPS tracking data. The term Pr represent the probability that a declaration number i of product j contains an infractionwhile $fq_{\_criteriaij}$ represents the frequency of infringements associated with a particular criterion observed over the assessment period. The error term is ε_{ij} while α and β are the parameters of the equation to be estimated.

It should be noted further that, there are two kinds of thresholds in Fig. 2: threshold R which refers to risk level assessment thresholds as per the defined risk categories and the risk associated with each new declaration is derived from the econometric Eq. 1 and second threshold is the thresholdT which refers to transit time threshold and this is the threshold discussed in this article. From Laporte's work, his findings (inspect 20.6% to capture 96.6% of infractions) is used as is in this work as a starting point in determining the possible improvements on infraction detection of the new proposed system using a posteriori procedures together with GPS tracking data.

Simulation procedure: Simio Simulation Software package was used in developing a simulation model for the proposed system summarised in Fig. 1 and 2. As stated in introduction section, one of the objectives of this study was to simulate GPS tracking of cargo trucks as they travelled from various ports of origin to a selected border post, the Beitbridge border post in the present study. The simulation of GPS cargo trucks tracking data and its communication to custom's system had two primary objectives: firstly, identifying cargo trucks that would have deviated from the set travel routes; and secondly, identifying cargo trucks that would have taken unduly long on their journey from their ports of origin to the border post. Cargo may take unduly long to get to the border post for number of reasons which include undue and unscheduled stoppages, deviation from the set routes and so forth.

The simulation model consisted of six South African major cities, the ports or towns of origin, the road networks and routes from these towns/cities that are generally, used in traveling to the chosen border, the Beitbridge border post. The simulator was calibrated using data obtained from the GIZ website, field data. This study used GPS tracking data generated by a fleet of more than 4000 trucks traveling across all of the major routes forming part of the so-called North-South Corridor. Found at the border between South Africa and Zimbabwe, Beitbridge is one of the major border posts along this corridor and is known to represent one of the major transit delays for cargo. The data from GIZ website include the distances between towns and average speeds of cargo truck as observed on different sections of the route. After the development of the simulator, it was then run for a period of 8760 h with 100 replications. In developing the simulator, the steps that were followed included:

- A targeted trade corridor network was developed modelled and simulated using Simio Simulation Software
- The simulator was then calibrated and validated using historical as well data from GIZ
- Various scenarios were then investigated

Cargo trucks deviations from the set routes are of two main kinds: the cargo trucks that deviate from the set routes to a secluded places or to some other warehouse or undue stoppages at undesignated places in order to illegally load additional or offload some cargo/goods and those that randomly deviate and stop with no intention of engaging in any form of malpractice. These deviations and stoppages have an effect of increasing the transit time from port of origin to the border post. It would not be unreasonable to assume that cargo that deviate with full intention of engaging in some form of malpractices would, on average have a higher deviation tendency (probability) compared to cargo that deviate without any intention to engage in malpractices. In the simulator, the deviation probability for cargo which deviates for some malpractice prone activities was set at twice as much as that of cargo that deviates but not involved in any malpractice activities. As stated above, the deviations from the set routes and undue stoppages inevitably results in increase in transit time from the port of origin to the border post. In taking this into account for the two kinds of deviations, the simulator was designed to stochastically apply a delay to each cargo that deviated from set routes or unduly stopped at undesignated places. The delay for each of these two kinds of deviators was generated by a unique Probability Distribution Function (PDF) associated with either of the first or the second scenario as explained above in this case a random triangular (min, mode, max) distribution was used as it allows for wider variability. The values of min, mode and max used in the simulator were informed by transit times from historical data, (Fitzmaurice, 2012) as well as a detailed analysis of possible conduct of truck drivers on the way to the border.

After taking into account all these possible activities, the selected PDFs for the two classes of truck drivers were triangular (1, 2, 5) for cargo that deviates with no intention of engaging in malpractices and triangular (2, 4, 7) for deviators with intention to engage in malpractices.

After the simulation was done, the results were then interpreted taking into account the findings by Laporte on the use of a posteriori knowledge in risk assessment. The assumption was that by including GPS real-time tracking data in customs database, then a posteriori intelligence would be enhanced.

Simulator calibration: The data from GIZ website was used in calibrating the simulation model. Some of the essential data from the GIZ website is summarised in Table 1. The data on the website is detailed to the extent of providing observed average speeds of cargo trucks in different sections of the respective routes. In developing the simulator, the data in Table 1 was used in the following ways: the distances of various towns from the border was used in setting the logical distances in the simulator in order to correspond to the actual distances travelled by cargo from various towns, the Simio Simulation package supports this kind of functionality; the average speeds were used to impart cargo trucks appropriate travel speed for various sections of the routes and the transit time was mostly important on arriving at the border post where the custom's risk engine would determine the risk of the arriving cargo, taking into account the amount of transit time the cargo deviated from expected transit time. The average speed data for different towns was used in estimating the transit time to the border post from respective ports of origin. The GIZ data shows overall average speed of 25.99 kmh^{-1} with standard deviation of 12.11 kmh^{-1}.

Table 1: Average speeds and transit times

Town name	Distance (km)	Average speed (kmh^{-1})	Travel time (h)
Cape Town	1941	35.61; σ = 18.64	54.51
Durban	1105	12.58; σ = 7.44	87.84
Port Elizabeth	1588	35.32; σ = 18.65	44.96
East London	1505	42.47; σ = 20.71	35.44
Maputo	955	16.70; σ = 10.45	57.15
Johannesburg	538	13.26; σ = 10.12	40.57

Table 2: Simulation average speeds and transit times

Town name	GIZ Speed (kmh^{-1})	Simulation Speed (kmh^{-1})	Simulation travel time (h)
Cape Town	35.61; σ = 18.64	36.02	58.35
Durban	12.58; σ = 7.44	16.90	73.42
Port Elizabeth	35.32; σ = 18.65	29.43	58.47
East London	42.47; σ = 20.71	32.12	51.37
Maputo	16.70; σ = 10.45	16.08	65.19
Johannesburg	13.26; σ = 10.12	18.03	35.94

It is also mention-worth that, the data from the GIZ website includes information on the minimum and maximum speeds observed on various routes as it were. This data was used in the simulation to determine the parameters of the input distributions to drive the simulation. For example, the route from Cape Town to Bloemfontein, the average speed is 34.69 kmh^{-1} and the observed minimum and maximum speeds are 33.3 and 35.84 kmh^{-1}, respectively. Therefore, all cargo trucks on entering this route their speeds were then driven by the triangular distribution, random_triangular (33.3, 34.69, 35.84) as used in Simio Simulation package. This procedure was applied to all other routes.

After the development of the simulator model and application of inputs to drive the model, validation was thereafter done using GIZ website data. The simulation was then run for a period equivalent to 12 months (8760 h) with 100 replications. In order to take into account, the warm-up effect at the commencement of simulations, the simulator was run for with 100 h as warm-up period. The 100 h warm-up period minimises the simulation start-up bias. Simio Simulation package can be set to clear or reset the recorded statistic from the start of the simulation to the end of the defined warm-up period and thereafter it starts recording new statistics (Kelton *et al*., 2014). Generally, the warm up period has to be as close as possible to the steady state run-time.

Table 2 shows the simulation results which shows values that are comparable to the GIZ data in Table 1. From GIZ data, the overall average speed is 25.99 kmh^{-1} while the simulation overall average speed is 24.76 kmh^{-1}. When the t-test, (Dass, 2014; Sheskin, 2011) was applied in comparing GIZ data (Table 1) with the simulation results (Table 2), the t-values were 0.189 and -0.401 for average speeds and transit times, respectively. The 5% value of t for 10 degrees of freedom is 2.228 which is higher than both calculated values of t, therefore, the difference between the means is not significant. It is also worth noting that confidence intervals within 90 and 95% ranges are not uncommon for studies of this nature where there is wider variability (Wegner, 2012). The inherent uncertainties associated with human behaviour (driver behaviour), makes it difficult to get higher levels of 0 precision in the results.

Considering and comparing the simulation results (Table 2 to GIZ values (Table 1) their respective average transit times, 57.12 and 53.41 h as well as the t-test results discussed above; it can be concluded that the simulator had been calibrated within the range of acceptable statistical uncertainty (Wegner, 2012; Vining, 1998).

After calibration of the simulator, it became possible to estimate transit times of cargos from their respective ports/towns of origin to the border post. This capability would then enable CREMS to estimate risk associated with each arriving cargo at the border post depending on the level of deviations from standard transit time for the set routes (geo-fenced routes). It should be added and further clarified that in the envisaged system, CREMS would determine the estimated arrival times using multiple means including the use of look-up tables and so forth.

Simulation scenarios investigated: The following three scenarios were investigated in this study: the impact of cargo deviation from the set routes and how this impacts on transit time from port of origin to the border post and its impact on infraction detection ability of the proposed GPS facilitated new system. The input variable was the degree or proportion of cargo that deviated from the set route and that variable was called Deviation Probability (DevProb). This variable was used to determine, at selected road junctions in the model network, the probability of cargo deviating from the normal route and every cargo that so, deviated was then subjected to a delay time determined by the PDFs (Probability Distribution Functions) explained earlier. DevProb was then varied from 1% to some value, for example, 50%.

The impact that the proportion of infraction-prone cargo has on transit time from port of origin to the border post and how it impacts on infraction-detection capability of the proposed new system. The input variable was the proportion of infraction-prone cargo (or Infraction probability (InfraProb)). It is note-worthy that, the simulator stochastically imputed infraction status at the time of generating cargo (entities) at the model entities source, on some model entities (cargo trucks) according to the set value of InfraProb parameter and transit time from port of origin to the border post and transit time thresholds (threshold) and its impact on infraction-detection capability of the proposed new system. Threshold was set to a specific level (% of average transit time for a specific route) and any cargo whose transit time was above the threshold were then sent for detailed inspection.

Investigating these three scenarios enables the determination of possible improvements on infraction detection and border posts transit time. Further, the knowledge of the average number or percentage of cargo trucks that deviate from the agreed routes will allow improvement on custom's a posteriori intelligence in risk assessment and infraction-detection thereby avoiding unnecessary and uncalled for intrusive inspections.

RESULTS AND DISCUSSION

Infraction prevalence: Before a detailed discussion of the results is presented, it is apposite to briefly discuss the assumptions upon which the analysis of the results is predicated upon. It is assumed that the infraction prevalence in the cross-border trade corridor is 10% of all cargo trucks plying the targeted trade corridor. The work by Fitzmaurice (2012) and Laporte (2011) indicate that the total infractions caught by customs over a specified period is only 1% of all cargo trucks plying the trade corridor. The 1% seems to be too low and if it were to be true and correct then it would imply that 99% of traders are compliant and good model citizens/traders. But according to the reports by United Nations Economic Commission for Africa as well as by Zvekic (United Nations, 2016; Zvekic, 2002), the prevalence of corruption as a social problem in the SADC region is 74.1% and the number of citizens who are required to pay bribes in the SADC region is 14.7%. With these historical figures on corruption in the SADC region and other parts of the world, the assumption of 10% infraction prevalence is actually a conservative and a reasonable assumption. Therefore, the analysis of the results is predicated on the 10% assumption of infraction prevalence.

In order to aid clarity, it also important to clarify a few terms used in the process of analysing the results. The term "inspection selection rate" which is used interchangeably with the term "Laporte's selection rate" refers to the percentage (%) of all cargo which is selected for detailed inspection see column 1 in Table 3.

Table 3: Comparison of infractions detection capability between Laporte procedure and the proposed system with transit time threshold set at 10% and overall infractions prevalence set also at 10% of 104697 of total cargo

1	2	3	4	5	6	7	8
0.1	94	0.9	595	5.7	7	588	98.8
1.2	442	4.2	648	6.2	63	585	90.3
2.1	563	5.4	693	6.6	114	579	83.5
2.5	619	5.9	714	6.8	135	579	81.1
3.3	717	6.8	752	7.2	177	575	76.5
4.4	802	7.7	804	7.7	234	570	70.9
6.7	911	8.7	909	8.7	352	557	61.3
9.2	994	9.5	1028	9.8	484	544	52.9
12	-	-	1163	11.1	641	522	44.9
15	-	-	1306	12.5	801	505	38.7
18	-	-	1448	13.8	962	486	33.6
20.6	1067	10.2	1565	14.9	1087	478	30.5
100	-	100.0	10470	100	-	-	-

1: Inspection rates (levels) from Laporte data (%); 2: Laporte accumulated infractions (#); 3: Laporte accumulated infractions (%); 4: Simulation accumulated infractions when applying Laporte inspection rates plus transit time thresholds (#); 5: Simulation accumulated infractions (%); 6: Simulation accumulated infractions caught when applying Laporte rule only (#); 7: Simulation accumulated infractions caught when applying transit time rule only (#); 7: Percentage of infractions caught using transit time rule only per inspection selection rates (column 1) (%)

Average transit time: Since, in the proposed new system average transit time will be used in screening potentially non-compliant cargo from compliant cargo, there is therefore, a need for the system to be able to differentiate transit times for the following three categories of cargo:

The cargo which deviates from the set routes or which randomly stops with intention to engage in some form of malpractices, the HIR cargo transit time, however, not all HIR cargo deviate from set routes and therefore, the overall transit time of this class of cargo comprise the average of these two.

The cargo which deviates from the set routes or that randomly stops without any intention to engage in malpractices, the LIR cargo transit time. The cargo which is compliant which does not deviate or make undue random stops, the NR cargo.

Detectable infractions from GPS data: Table 3 shows Laporte's infraction detection results against the simulation results on infraction detection when transit time threshold was set at 10% of the average transit time per given travelling route. Since, the simulator was not calibrated with or for Laporte's data, it was necessary to reconfigure the calibrator before generating the results shown. In particular, the number of entities (cargo trucks) was set to the same number (104697) as in Laporte's case, the run time of the simulator was set to 1 year (8760 h) similar to Laporte's observation period and the possible total number of infractions (detected plus the non-detected) was set to 10% of all cargo trucks plying the trade corridor under study. The 10% assumption was informed by the reported level of corruption (Thomas *et al*., 2007) and that only 1% of infractions is normally detected (Fitzmaurice, 2012; Laporte, 2011). Further motivation for the 10% has been discussed above:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\tilde{s}_1^2}{n_1} + \frac{\tilde{s}_2^2}{n_2}}} \quad (2)$$

The t-test, Eq. 2 (Sheskin, 2011) was then used to see if the simulation results and Laporte's results have been drawn from the same population. In Table 3, the t-test was applied to columns 2 and 4 and the calculated value of t was -2.01 and the table value of t at 5% and 19 degrees of freedom was found to be 2.09. Since, the calculated value of t is <2.09, the difference between the means of the samples is not significant in other words, samples have been drawn from the same population, thus, validating the simulation results.

The accumulated simulation infractions in column 4 of Table 3 are obtained by applying the risk assessment procedure summarised in Fig. 2. The inspection selection rates shown in column 1 of Table 3 are each applied one after another in the block "Apply Laporte selection procedure" in Fig. 2 together with the transit time threshold criteria to select potentially high risk cargo. As can be seen in Table 3 at inspection selection rate (column 1) of 9.2% the proposed system was able to capture 9.8% of infractions when the transit time threshold was set at 10% compared to Laporte procedure which captures 9.5% of the infractions. At inspection selection rate of 12% (column 1), the proposed system can capture up to 11.1% (column 5) of infractions compared to 10.2% (column 3) which is captured at 20.6% (column 1) inspection selection rate in the Laporte procedure. Therefore, the proposed system is evidently superior in infraction detection.

Bi-layered risk assessment: The aim of the proposed system is to improve upon a posteriori risk assessment procedure for customs as was proposed and subsequently tested by Laporte. The proposed system improves risk assessment by using a two-layer risk assessment procedure unlike a posteriori risk assessment procedure. Figure 2 summarises the flow diagram showing the two-layered risk assessment in the proposed system. Upon arrival at a border post, cargo is separated into two categories; the cargo that did not deviate from the set routes and the cargo that would have deviated from the set routes as detected through GPS or would have made unscheduled stoppages. Risk assessment using a posteriori procedure is applied to each of these categories and risk score calculation is done according to the econometric Eq. 1. But for the cargo that would have deviated from the set routes or those that would have had unscheduled stoppages, additional selection criterion is used to decide whether the given cargo should be inspected intrusively or not. The additional criterion used is the transit time from port/town of origin to the border post and here, the determination is whether a given cargo has transit time which is above the set threshold for the respective set routes.

It should be noted from Fig. 2 that the proposed system obtains its advantage over the basic a posteriori procedure in that, it has the additional risk parameter, GPS tracking data as shown in econometric Eq. 1 as well as the two-layered risk screening procedure. The GPS tracking data provides real-time cargo monitoring intelligence tocustoms and other relevant authorities, thereby, enriching the customs database with risk assessment data. On the other hand, the two-layered risk screening procedure comprise of a posteriori risk screening procedure as proposed by Laporte together with the proposed GPS tracking data enhancement and the second screening layer is provided by the transit time of each cargo as measured against the known average transit time for given ports or towns of origin and the set transit time threshold. Expressed differently, if T (≡100% in Fig. 2) represents the total cross-border cargo trucks within the trade corridor, ND represents cargo trucks that did not deviate or did not unduly stop and D (≡x% in Fig. 2) represents cargo trucks that deviated from set routs or unduly stopped at undesignated places. Therefore:

$$T = N_D + D \tag{3}$$

On applying the Laporte's 20.6% inspection selection rate gives the total number of cargo trucks to be inspected as:

$$0.206T = 0.206N_D + 0.206D \tag{4}$$

Equation 6 is a generalisation of Fig. 2 assessment procedure where α is the chosen inspection selection rate at any given time:

$$\alpha T = \alpha N_D + \alpha D \tag{5}$$

In Fig. 2, the main branch marked as (100-x%) is the same as the ND while the branch marked as x% is the same as D in Eq. 3. In Eq. 4, 20.6ND and 20.6D represent the blocks "apply Laporte selection procedure" for the respective branches of Fig. 2. For the minor branch (x%), after application of Laporte selection (20.6D) procedure as explained previously, a second screening which is based on transit time then follows as shown in Fig. 2. This second screening layer provides the additional screening capability over and above the addition of the GPS tracking data parameter used Eq. 1. The pertinent question should now be centered on finding the least possible improvement that the proposed system brings above the legacy system or the basic a posteriori procedure.

Infraction detection improvement: Estimation of the possible improvement that the proposed system can bring may be derived from the results in Table 3. Applying linear regression to Laporte data (column 2 of Table 3) and to the simulation data (column 4 of Table 3) give the following respective trend-lines equations:

$$f_1(x) = 37.28x + 482.39 \tag{6}$$

$$f_2(x) = 47.36x + 593.42 \tag{7}$$

The corresponding derivatives are:

$$f_1^{'}(x) = 37.28 \text{ and } f_2^{'}(x) = 47.36$$

Therefore, possible improvement is 27.04% {((47.36- 37.28)÷37.28)×100}. It is noteworthy that, the simulation results on accumulative infraction detections at column 4 of Table 3 has been shown through the t-test to be valid and belonging to the same population as the Laporte data on accumulative infraction detections. Therefore, the analysis and the consequent deductions based on the derived trend-lines equations should be acceptable. The results in Table 3 further show that, as the inspection selection rate (%) is increased, the proposed system further far outperforms the system based merely on a posteriori risk assessment procedure. For example, at inspection selection rate of 12% (column 1) for the proposed system compared to 20.6% (column 1) inspection selection rate for the system using a posteriori procedure, the proposed system outperforms the system based on mere a posteriori procedure by at least 8.8% {= ((11.1%-10.2%)÷10.2%)×100}. Another head-to-head estimation of possible improvement from Table 3 at inspection selection rate of 20.6%, the legacy system infraction detection rate is 10.2% while for the proposed system it is 14.9%. Therefore, possible improvement is 46.1% {= ((14.9%-10.2%)÷10.2%)× 100}. The average of these two figures (8.8 and 46.1%) is 27.45%.

Since, the accuracy of a posteriori risk assessment procedure is dependent on the quality of customs risk assessment database (Laporte, 2011) and since, the proposed system incorporates a posteriori risk assessment procedure, therefore as customs database becomes richer with data over time, the proposed system will inevitably improve as well. If the historical data in the customs database is to continue to have effect on risk assessment, it should be preserved in some way. To this end, it is further proposed that, the data be preserved using the so-called NFU (Not Frequently Used) algorithm. This algorithm is mostly used in operating systems when deciding the next page to be replaced (Tanenbaum, 2009). The essential aspect of NFU algorithm usable is that, the entire contents of the database are divided by a chosen factor (divide by ten, for example) at the end of each cycle (which might be yearly or after two years and so on); in this way, historical infractions continue to contribute to the econometric equation, albeit at a lesser extent, in the determination of the risk factor associated with each new declaration. Necessary modifications to the econometric equation maybe required.

If the data from the GIZ website which was used to calibrate the simulator is assumed to be correct, then the simulation results produced should be closely reflective of what would happen in reality. Should customs adopt the proposed system, then the role players in the trade corridors can take full advantage of the results of this study by insisting on transporters to meet cost-effective transit times and avoid deviating from set routes.

Pilot study: A pilot project which bears close resemblance to the study described in this article was done by Siror *et al*. (2010). The research project was done in Kenya. The objectives of the pilot project included investigating how to use technology in curbing unlawful discharging of cargo into Kenyan market which would be destined for export or transit to other countries. Siror *et al*. (2010) used various technologies which included RFID, GPS and etcetera. The research project involved the use of RFID electronic seals that were used in sealing cargo as well as cargo truck container doors in order to prevent unauthorised tampering with the cargo in transit. Cargo trucks were tracked as they travelled from their respective towns or ports of origin up to and into their ports of exit. Furthermore, the integrity of electronic seals were checked along the route using electronic readers. The GPS technology was used in tracking cargo and in insuring that cargo trucks would not deviate from their set routes from their respective towns or ports of origin to their ports of exit. Usually, when cargo trucks deviate from their set routes, more often than not such deviation is normally linked with some form of malpractices, for example, the addition or removal of illegal cargo from the truckload of legal cargo (Thomas *et al*., 2007). In this pilot project, a total of 284 pilot trips were investigated. Siror *et al*. (2010) found that of the 284 pilot trips, only 74 trips recorded errors which were associated with RFID seals as well as GPS errors (Johnston, 2003). Based on these given figures, the system, therefore had a success rate of 74% = {(284-74)÷284}. It was further reported that, the transit time for cargo from their respective towns or ports of origin to their ports of exit decreased from a range of 33-100 h to a range of 20-80 h. It was also reported that there was 45% increase in efficiency on cost savings and on turn-around times.

The work done by Siror *et al*. is important in that, it showed that by using various technologies together, beneficial and reliable real-time monitoring of cargo in transit was achievable. The research further showed that there is potential impact in reducing transit time of cargo thereby improving on cost savings and turn-around time. However, the pilot work did not look into the possibility of integrating real-time monitoring data with other possible customs risk assessment data for risk profiling of transit cargo. This is one the aspects considered in the present research.

The researchers in the present study recently entered into a consultancy contractual agreement with a certain Zimbabwean firm that worn the tender to improve the Zimbabwean Beitbridge border post operations. One of the terms of the agreement is that, the present researchers spearhead incorporation of the present study and any other previous studies into an assortment of pilot projects leading to commissioning of a new custom's system in the near future. However, for the complete benefits of the system to be realised, a similar or comparable and compatible system will need to be implemented on the South African side as well.

CONCLUSION

Based on the simulation results and the analysis applied there to, it can be concluded that the proposed system, when compare to using a posteriori procedure only, is capable of achieving at least 27.45% improvement on customs risk assessment and infraction-detection. Furthermore, besides improving customs risk assessment and infraction-detection, the proposed system also serves as a regulatory measure in that, the system will allow most compliant cargo to go through a border post with minimum delays compared to deviant and non-compliant cargo. Consequently, efficiencies of trade corridors are bound to improve accordingly. The economic benefits for African countries would be immense in that, cross border traders will experience reduced delays at border posts and governments will still derive substantial revenue from customs duty/tax owing to improved infraction-detection system.

The work described in this article has shown that, it is possible to reduce the long transit times that cargo experience at border posts through implementing of a new system which incorporates a posteriori procedure, real-time monitoring of cargo and other ancillary technologies. Risk assessment through the use of a posteriori procedure enhances customs risk assessment by combining, through econometric equation, historical infractions record of a trader, thereby, permitting a more intelligent way of selecting cargo that should be intrusively inspected. On the other hand, GPS real-time tracking and monitoring of cargo as it travels from the towns/ports of origin to the border post improves the efficiency of trade corridors in multiple ways including: improved driver behaviour, since, any undue deviations from the set routes or undue and long stoppages will be picked up by CREMS through GPS-based data with adverse repercussions; custom’s risk assessment will also be improved and as a result processing of cargo will become faster because the combined risk assessment procedures will enable customs to capture more infractions by inspecting fewer cargo trucks. It should be pointed out that, the other ancillary technologies to be used in the proposed system include RFID systems which may comprise of RFID readers, RFID tags and RFID electronic seals. All these technologies and procedures/techniques in the proposed system will inevitably have a significant and positive impact on the efficiency of the target trade corridors. However, one question that still remains to be answered is whether the reduction in customs processing time or efficiency improvement would be good enough to take Africa’s trade corridors one step towards competitiveness on international trade stage (Norov and Akbarov, 2009; Barka, 2012).

Trade corridors are socio-technical systems where the human element is quite dominant. Inevitably, in introducing a new operandi model, the impact of human conduct must be taken into account if one is to come up with a more realistic system. Therefore, the proposed future research work should include:

Incorporating human conduct in modelling trade corridors and border posts processes. Implementing a system of rewarding both truck drivers and customs officials who conduct themselves well. For drivers, good behaviour includes compliancy with set routes and agreed conduct while for customs officials this may include those who consistently process cargo within agreed time periods.

Proposition of appropriate regulatory framework that makes it compulsory for all cargo trucks to be installed GPS module and allowing the GPS data to be shareable customs systems.

Developing a complete internet enabled trade corridor system which enables full transparency and visibility of all registered cargo as they move-about within the trade corridor(s) as well as cross-border movements (Lusanga *et al*., 2014). Completing the investigation of the efficiencies of the entire trade corridors, starting from the point of origin of the cargo to the point where the cargo crosses the border posts. This requires the combination of the work in this article and the work that was done by Hoffman *et al*. (2015) which investigated border posts processes and how they can be optimized by a combined use of RFID technology and procedural re-alignment. It is worth investigating the impact of using NFU (Not Frequently Used) algorithm (Tanenbaum, 2009), on the customs database compared to the cyclic operandi as proposed by Laporte.

REFERENCES

Alises, A. and J.M. Vassallo, 2016. The impact of the structure of the economy on the evolution of road freight transport: A macro analysis from an Input-Output approach. Transp. Res. Procedia, 14: 2870-2879.

Barka, H.B., 2012. Border posts, checkpoints and Intra-African trade: Challenges and solutions. African Development Bank, Abidjan, Côte d’Ivoire, Africa. https://www.africabib.org/rec.php?RID=39889678X

Buyonge, C. and I. Kireeva, 2008. Trade facilitation in Africa: Challenges and possible solutions. World Customs J., 2: 41-54.

Dass, H.K., 2014. Advanced Engineering Mathematics. S Chand & Company (Pvt.) LTD., New Delhi, India, ISBN-13: 9788121903455,.

De Wulf, L. and J.B. Sokol, 2004. Customs Modernization Initiatives: Case Studies. World Bank, Washington DC., UDA., ISBN: 9780821383735, Pages: 132.

Deborah, K.E. and P. Low, 2013. Global Value Chains in a Changing World. World Trade Organization, Geneva, Switzerland, Pages: 411.

Fitzmaurice, M., 2012. TLC report on Beitbridge, Chirundu, Kasumbalesa and Nakonde. Transport and Logistics Consultants, Port Elizabeth, South Africa.

Havenga, J.H., Z.P. Simpson, A. De Bod and N.M. Viljoen, 2014. South Africa's rising logistics costs: an uncertain future. J. Trans. Supply Chain Manage., 8: 1-7.

Hoffman, A., A.D. Coning, E. Bhero and K. Lusanga, 2015. Impact of a radio-frequency identification system and information interchange on clearance processes for cargo at border posts. J. Transp. Supply Chain Manage., 9: 1-14.

Hoffman, A.J., K. Lusanga and E. Bhero, 2013. A combined GPS/RFID system for improved cross-border management of freight consignments. Proceedings of the 2013 Africon Conference, September 9-12, 2013, IEEE, Pointe-Aux-Piments, Mauritius, pp: 1-8.

Johnston, R.G., 2003. Tamper-indicating seals: Practices, problems and standards (No. LA-UR-03-0269; LA-UR-03-269). Proceedings of the Conference on World Customs Organization Security Meeting, February 11-14, 2003, Los Alamos National Laboratory, Brussels, Belgium,.

Kelton, W.D., J.S. Smith and D.T. Sturrock, 2014. Simio and Simulation: Modeling, Analysis and Applications. 3rd Edn., Createspace Independent Pub, South Carolina, ISBN: 9781492116424, Pages: 104.

Laksmanan, T.R. and W.P. Anderson, 2002. Freight services and economic growth: A synopsis of white paper. M.BA. Thesis, The US Department of Transportation, Federal Highway Administration, Washington DC., USA.

Laporte, B., 2011. Risk management systems: Using data mining in developing countries' customs administrations. World Customs J., 5: 17-28.

Lusanga, P.K., A.J. Hoffmanm, A. de Coning and E. Bhero, 2014. A simulation strategy to optimize the design of internet enabled logistics services. Proceedings of the 17th International IEEE Conference on Intelligent Transportation Systems (ITSC), October 9-11, 2014, IEEE, Qingdao, China, pp: 2693-2699.

Norov, L. and D. Akbarov, 2009. Customs-time for a change. Prob. Econ. Transition, 52: 47-60.

Sheskin, D.J., 2011. Handbook of Parametric and Nonparametric Statistical Procedures. 5th Edn., CRC Press, London, UK., ISBN: 9781439858011, Pages: 886.

Siror, J.K., L. Guangun, P. Kaifang, S. Huanye and W. Dong, 2010. Impact of RFID technology on tracking of export goods in Kenya. J. Convergence Inf. Technol., 5: 190-199.

Tanenbaum, A.S., 2009. Modern Operating Systems. 3rd Edn., Pearson Prentice Hall, New Jersey, USA., ISBN: 9780136006633, Pages: 1072.

Thomas, V., A. Khadr and N. Girishankar, 2007. World bank country-level engagement on governance and anticorruption. IEG World Bank, Washington, DC., USA. http://ieg.worldbankgroup.org/sites/default/files/Data/reports/gac_eval.pdf

UNIDO., 2015. Global value chains and development. United Nations Publication, New York, USA. https://www.unido.org/sites/default/files/2016-03/GVC_REPORT_FINAL_0.PDF

United Nations, 2016. Measuring corruption in Africa: The international dimension matters. United Nations Economic Commission for Africa, Addis Ababa, Ethiopia. https://www.uneca.org/sites/default/files/PublicationFiles/agr4_eng_fin_web_11april.pdf

Vining, G.G., 1998. Statistical Methods for Engineers. Duxbury Press, Florida, USA., ISBN: 9780534237066, Pages: 479.

Wegner, T., 2012. Applied Business Statistics: Methods and Excel Based Applications. 3rd Edn., Juta Academic, Cape Town, South Africa, ISBN:9780702177743, Pages: 420.

Zvekic, U., 2002. United Nations office on drugs and crime regional office for Southern Africa. Corruption & Anti-Corruption in Southern Africa, Africa.