A combined GPS/RFID system for improved cross-border management of freight consignments

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***Abstract*—Inefficiency of road freight transport is one of the primary factors that hamper the economy of sub-Saharan Africa. Long delays experienced at border posts are the single biggest contributor towards the slow average movement of freight. Cross-border operations are complicated by the conflicting security objectives of customs authorities versus efficiency objectives of transport operators. It furthermore suffers from illegal practices involving truck drivers and customs officials. In theory the efficiency of cross-border operations can be improved based on the availability of more accurate and complete information – the latter will be possible if different stakeholders can exchange data between currently isolated systems. This paper firstly quantifies the size of the problem and estimates the potential economic benefits that will be created by improved cross-border operations. It then proposes a combined GPS/RFID system that can provide the required level of visibility to support improved operational management, resulting in a simultaneous increase in the security and efficiency of cross-border freight operations. A brief cost-benefits analysis is performed to show that the expected benefits from such a system will by far exceed the costs of implementation.**

Keywords—road freight transport, cross-border, customs processes, GPS tracking, RFID

I. INTRODUCTION

Globalization and the increased importance of international trade have resulted in steadily increasing levels of international freight. While much of this freight is ocean bound, road transport remains an important link in multi-modal freight supply chains [1]. On the African continent this dependence on road transport is even more prominent due to the absence or bad state of railway lines. African furthermore has many landlocked countries, with the result that a significant portion of road freight must travel along multinational corridors [1]. While many economic regions are gradually doing away with the charging of customs duties at border posts [2], the opposite is true in Africa, where the majority of countries are still dependent on customs duties as their primary source of state income [3]. Stringent controls are therefore applied at most border posts to ensure that freight does not leak into or from a country before the required duties have been paid.

The effective management of road transport is complicated by the involvement of a wide spectrum of independent stakeholders. The cross-border movement of a freight consignment includes at least the cargo owner (or consignor), the transport company, potentially a transport broker, a freight forwarder, a clearing agent, roads agencies, customs authorities on each side of the border, and a customer (or consignee). While the commercial players have objectives that are well aligned and aimed at operational efficiencies, the agencies responsible for protecting roads infrastructure and collecting customs duties are more concerned about the effectiveness of control measures aimed at the prevention of illegal practices.

Current cross-border freight management systems are characterized by a lack of transparency from the perspective of the consignor and consignee and by little coordination between the actions of different role-players. The lack of visibility of operations at ground level results in long average delays at border posts accompanied by many corrupt practices - often these two go hand in hand [4]. While lacking integration between the systems operated by different stakeholders is partly to blame, deliberate manipulation of the process by human operators (who know that their actions are difficult to police) also plays a major role.

This paper will focus on cross-border operations as practiced at a representative sample of border posts in Eastern and Southern Africa. The first aim is to quantify the potential economic value that can be created by improved operational practices at border posts. Estimates are made based on practical studies performed at border posts to measure the average delays experienced by freight consignments [5,6].

Secondly the paper proposes an improved cross-border management concept, based on the use of information and communication technologies and on the integration between the systems operated by private and public sector stakeholders. It is demonstrated that the exchange of more complete information sets between freight consignors and customs authorities can lead to the more efficient processing of consignments through the border, resulting not only in faster cross-border movements but also in increased accuracy in the detection of non-compliant consignments.

Thirdly the paper proposes an integrated system to support the proposed new management concept, utilizing GPS

information from existing tracking systems, complemented by passive and active RFID monitoring of vehicles and freight, to feed customs risk engines with richer data sets leading to more accurate decision-making. Lastly the paper performs a cost-benefit analysis to determine whether the proposed new concept can be expected to create more benefits than the estimated cost of implementation.

II. SURVEY OF EXISTING CROSS-BORDER MANAGEMENT SYSTEMS

It is clear from the introduction that the most critical factor in the cross-border management process is the customs system being applied. The processes enforced by customs authorities can be broadly divided into the submission of information based on which customs makes a decision about the level of risk represented by the respective consignment, and the physical inspection of goods that have arrived at a border.

Whereas countries like the USA and Japan have implemented the electronic declaration of goods as early as the 1980's [2], many African countries still rely on the manual submission of a road manifest when the truck arrives at the border [4]. As a consequence of the manual nature of such customs processes there are many opportunities for bribery and collusion – research has indicated that the level of corruption tends to be directly related to the amount of interaction between truck drivers and officials [4].

South African Revenue Services (SARS) is leading the way in Eastern and Southern Africa, with a new Automated Cargo Management system [7] that involves the submission of a Road Freight Manifest through EDI (electronic data interchange) – this document carries a unique number and contains a report of the cargo carried on the truck. Once the SARS official has verified that an electronic pre-declaration has been received for a consignment arriving at the border a decision is made using an automated risk management engine whether to inspect the consignment. If the consignment is cleared a gate pass is made out and dispatched to the customs gate before the vehicle is allowed to move towards the customs gate; when the respective vehicle arrives at the gate an official verifies the vehicle against the gate pass before it is allowed to proceed to the other side of the border, and the gate pass is added to the list of acquitted vehicles.

While this already represents a significant improvement on systems applied at most other African borders, the SARS process still does not include a physical reference or link between the documentation and the actual cargo or to the transport vehicle. Should the official at the customs gate be in collusion with the truck driver one of the following is possible:

- a vehicle can be allowed to proceed through the customs gate with the associated gate pass (in which case uncleared cargo is allowed into a new jurisdiction), or
- alternatively a gate pass can be processed without an actual vehicle moving through the customs gate (in which case goods destined for export remain in the country and evades either customs duties or value-added tax).

III. ECONOMIC COST OF INEFFICIENT BORDER OPERATIONS

The inefficiencies at border posts can be broken down into a number of distinct elements; the most important of those are listed below:

1. The reduction in utilization levels of trucks and drivers due to cross-border delays, resulting in a smaller average number of completed trips per truck per month.

2. Losses to the operations of customers waiting for delayed freight consignments in terms of lost production and lost retail sales.

3. Loss of customs income due to the leakage of illegal freight across borders.

4. Indirect costs to the regional economy due to loss of foreign trade resulting from uncompetitive transport costs and unpredictable delivery times.

The last item in the list below most likely has by far the biggest overall impact on the countries involved: an increasing movement towards just-in-time production practices makes predictable delivery times an essential element to compete globally. This is however also the most difficult cost to accurately quantify. The second and third items are more directly measurable, but require insights into the accounts of individual commercial and governmental players.

The only source of accurate data that was available for this research work was the results of a number of cross-border studies that manually collected data on the average time spent at borders by freight consignments [5, 6]. Information was also obtained from several commercial transporters about the actual income and cost figures applicable to typical road freight operations on African corridors. The availability of this data made it possible to accurately estimate the economic losses suffered by transport companies due to increased round-trip times for trips to African destinations. For this reason the paper focuses only on the first cost element as identified above to quantify losses and to justify an improved system. This approach will lead to conservative results for the cost-benefit analysis that is performed in the last section of the paper.

The costs associated with reduced utilization of trucks due to cross-border delays is calculated based on the set of values as described in Table I below; these values were obtained from the operations of a transporter doing trips between South Africa, Zambia and the DRC [8]. Firstly we calculate the economics associated with an average cross-border trip, including total cost, income generated and profit. Using the average turnaround time we calculate the average monthly income, cost and profit for one truck.

The loss of income and profit per truck is then calculated by using the fraction of total trip time that is consumed by cross-border delays. Average waiting time at border crossings (39 hours) was calculated using studies that were conducted over several years, in each case involving the measurement of delay times for several hundred trucks over periods of several months. By calculating the total average border crossing times for the entire trip and subtracting this from the average trip duration we obtain the trip duration for zero border crossing delays. Using this figure it is possible to calculate the

monthly profits that can be generated per truck if border crossing delays were reduced to 2 hours, as shown in Table II.

TABLE I. ECONOMICS PER TRIP

Monthly interest rate	1.0%
No of monthly installments	120
Average cost of truck	$150 000
Monthly installment	$2 152
Average income per trip	$7 000
Average distance per trip (km)	4000
Average fuel consumption (km/l)	1.5
Cost of fuel per liter	$1.20
Average cost of fuel per trip	$3 200
Cost of driver per trip	$600
Additional cross-border expenses per trip	$600
Other costs per trip (tolls, etc.)	$150
Total trip costs excluding financing of truck	$4 550

TABLE II. MONTHLY PROFITS PER TRUCK

	Current scenario	Improved scenario
Average speed of travel (km/h)	70	70
Number of hours driving per day	8	8
Number of days driving per trip	7.1	7.1
Number of border crossings per trip	4	4
Average cross-border delay (days)	1.63	0.08
Total border delay per trip (days)	6.50	0.33
Average trip duration (days)	13.6	7.5
Number of trips per month	2.2	4.0
Income per month	$15 393	$28 089
Costs per month	$12 157	$20 410
Profits per month	$3 235	$7 679

In order to determine the overall impact on the regional economy we follow two alternative approaches:

1. Based on the assumption that improved efficiencies will result in increased demand for freight transport capacity, we calculate the total annual profits that can be generated by the same fleet of trucks currently doing cross-border trips from South Africa to neighboring countries. We use an industry estimate of 6,000 trucks used on a permanent basis for cross-border transport [6]. As displayed in Table III we obtain a figure of more than US$320 million in additional profits that can be generated by the same fleet of trucks in the absence of cross-border delays.

2. In reality it is possible that the total demand for road freight transport will not increase significantly when cross-border delays are reduced. The alternative approach hence assumes that the demand for road freight transport remains the same but that the need can be met using a smaller fleet of trucks. This will result in two benefits:

- There will be a saving in the total required investment into the regional truck fleet. As shown in Table III this reduction amounts to approximately US$ 410 million. Assuming an interest rate of 12% p.a. for lease purchases this positive impact on financing cost amounts to almost US$ 50 million per annum.

- As the smaller fleet will be operated more profitably there will still be an increase in total annual profits, albeit smaller than for case 1 above: the increased annual profits are calculated at just more than US$ 70 million, which is still a substantial figure.

It can hence be seen that the annual benefit of improved cross-border operations to the transport industry based on improved truck utilization on its own can amount to anything between US$ 70 million and US$ 320 million.

TABLE III. COMPARISON: CURRENT VS IMPROVED SCENARIOS

Constant number of trucks	**Current scenario**	**Improved scenario**
Number of trucks	6000	6000
Total number of trips per month	13194	24076
Total profits per month	$19 412 222	$46 074 876
Increase in annual profits		$319 951 846
Constant number of trips	**Current scenario**	**Improved scenario**
Number of trucks	6000	3226
Investment in trucks	$900 000 000	$493 193 717
Annual installments	$108 000 000	$59 183 246
Total profits per month	$19 412 222	$25 248 710
Increase in annual profits	-	$70 037 860

IV. IMPROVED CROSS-BORDER MANAGEMENT CONCEPT

The above discussion provides a clear incentive for the improvement of current efficiencies in cross-border operations. The central premise of total quality control — i.e. that higher quality can be attained at lower cost by proper management and operational design—is also applicable to logistics operations [9]. By using the right management approach, new technology, and re-engineered operational processes, we therefore believe that it is possible to achieve higher cross-border efficiency at lower cost.

To find a solution it is necessary to identify the primary contributors to the long delays experienced to move freight consignments across multinational borders. Based on recent studies performed in the cross-border field [4] it is clear that human processes are the primary culprits. The current nature of the process required to clear a consignment from customs involves amongst others the following:

- While declarations to customs can be made electronically before a consignment reaches the border (at least in some countries), it is still a requirement for physical paperwork to be submitted to customs at the border. In the process of passing documents from the truck driver to a clearing agent and then via a ‘runner’ to customs and back again, some of the paperwork is often mislaid, resulting in delays to generate new documents.

- The fact that a human controlled clearing process is required means that customs officials have the opportunity to manipulate the clearance process for personal gains. Studies have shown that the pre-declaration of documents, instead of expediting the process rather tended to slow it down in some cases [6]. The probable reason for this is that it allows unscrupulous customs officials more time to target consignments for deliberate delays in order to extort bribes.

The obvious solution to the problem is to automate the process of clearing consignments as far as is practically possible. In order to do this without increasing the risk of leakage of non-compliant goods across borders it will be necessary to rely to a larger extent on technology to complement human processes. Technology can be employed in several ways to provide customs authorities with much more detailed information on the physical status of freight consignments arriving at a border, allowing much more accurate discrimination between those consignments with a high likelihood of being compliant and the potentially suspicious ones that justify inspections. In addition to this technology can be utilized to police processes controlled by human operators to ensure that the appropriate steps are taken and that an audit trail exists of all actions taken by officials.

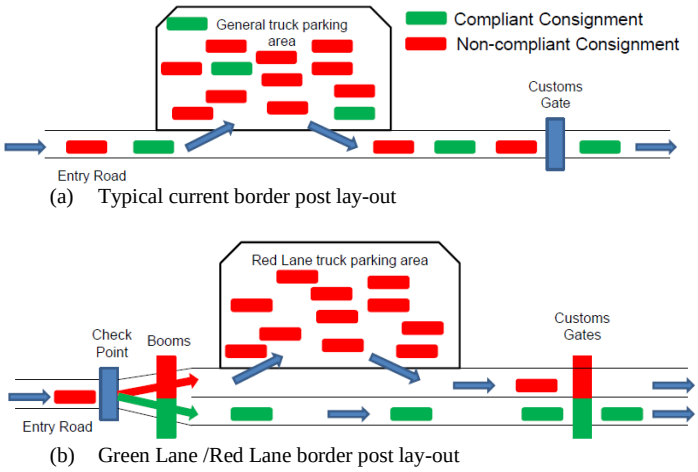
The improved cross-border management concept that is proposed in this paper consists of the following elements:

1. *A certification system for transporters combined with incentives for self-regulation*: The majority of transporters prefer to be fully compliant as long as they will receive benefits in the form of faster processing through borders. A certification system will however only work effectively if compliant consignments of certified transporters can be accurately distinguished from potentially non-compliant consignments of non-certified transporters.

2. *Automated channeling of freight traffic at border posts:* Ideally the system must automatically separate compliant from non-compliant traffic upstream from where trucks are finally cleared for crossing so that non-compliant traffic will have minimal impact on the flow of compliant traffic, as described in figure 1 below. This will effectively enable the implementation of a Green Lane / Red Lane system.

3. *Marking of documents:* Documents handed in for customs inspections must be marked with a machine readable code to enable automatic detection of paperwork when submitted and handled as part of the clearance process. This will serve as performance measurement tool, it can be used to verify that the contents were not manipulated and it will accurately link documents to related vehicles.

4. *The marking and automated detection of freight vehicles*: This will enable accurate and automated separation of certified and non-certified vehicles; secondly it will verify that all consignments for which paperwork was cleared actually crosses the border, and that only those vehicles for which the paperwork has been cleared can move through a customs gate.



(a) Typical current border post lay-out

(b) Green Lane /Red Lane border post lay-out

Fig. 1. Proposed change in traffic flow management at border posts

5. *The use of electronic seals on cargo containers*: This will reduce the risk that cargo has been tampered with as from when it was initially sealed. The electronic seal can be automatically checked at specific points along major corridors (typically at weigh bridge stations) to provide regular feedback that the consignment is still intact. Using more sophisticated technology it will even be possible to provide continuous feedback about the current status of seals [9,10].

6. *Providing customs authorities with detailed information on the movements of consignments as from the time of dispatch until it reaches the border*: If a vehicle is dispatched by a certified participant in good standing and this vehicles reaches the border within standard travelling times, without any unexpected deviations from the designated route, without any unexpected changes in weight and with the originals cargo seals still intact, it could reasonably be assumed that such a vehicle represents minimal customs risk. By automatically presenting customs with such information upon arrival at the border it will be possible to automatically process and acquit those vehicles that are fully compliant based on the above set of measurements. This will allow the customs authority to focus its limited law enforcement capacity on the minority of consignments that are not fully compliant.

7. *Using handheld technology*: Handheld computers can provide customs officials with real-time decision support while performing their inspection duties, while at the same time policing their actions to ensure that correct practices are applied to all consignments being inspected. This will prevent customs officials from delaying specific consignments without receiving corresponding instructions from the Customs Risk Engine. It will furthermore force officials to duly inspect cargo that has been selected by the risk engine and to report on findings. While these measures may not prevent all misconduct by customs officials, it will at least make them aware of the fact that their actions are visible within the larger system and that they will be held accountable if found to be in collusion with truck drivers or syndicates.

V. SUPPORTING TECHNOLOGIES

Many studies have been performed on the use of technology to improve the efficiency of global supply chains [11, 12, 13, 14, 15, 16]. From the above discussion it is clear that the envisaged cross-border management system will rely to a much larger extent on the use of technology compared to existing systems. The information to be supplied by technology systems can be broadly divided into two categories:

- Information available from existing systems used by transporters and roads agencies but that are currently not accessible to customs authorities – this primarily includes GPS tracking information reflecting truck movements, as well as weigh bridge information generated by roads agencies.

- Information generated by new systems to be deployed specifically for compliance purposes – this includes the identification of trucks (and electronic seals where applicable) upon arrival at the border and at the customs gate, the automated scanning of documents submitted on behalf of cargo owners and capturing of the actions taken by customs officials during inspections.

In this section we discuss these supporting technologies and the way that they can be integrated into customs operations.

A. GPS tracking

Practically all freight vehicles are currently equipped with GPS tracking systems as this is a requirement to qualify for insurance. The primary obstacle to use existing GPS tracking systems results from the fact that they were initially designed to support vehicle recovery and to a lesser extent fleet management. There is however no technological reason why selected subsets of tracking data cannot be made available to customs authorities for compliance purposes.

The certification system referred to above will include a requirement for compliant transporters to provide to customs access to GPS data that reflects the actual progress of trucks along the designated route to verify that no material deviations from the designated route occurred and that there were no unplanned stops. By linking this tracking information to the pre-declarations already submitted to customs it will be possible for customs to build up a behavioral profile for each consignment by the time that it reaches a border.

B. GSM and satellite communications

Most GPS tracking systems also include GSM communications capabilities; this provides a sufficient level of coverage on most of the major corridors into Africa. There are areas where coverage either does not exist or where the reliability is not sufficient. In such cases satellite communications will be the best option to provide close enough to real-time visibility to support the proposed concept. While this will add to the cost of the transport operation, such costs must be weighed against the current situation where the turn-around times of trucks are almost doubled due to border delays. The overall additional investment in communication systems will also be limited by the fact that most trucks are dedicated to specific routes – it will therefore only be necessary to install satellite communications on those trucks covering routes that do not have sufficient GSM coverage.

C. Electronic seals and Active RFID

It will be of additional value to both cargo owners and customs authorities if information is available in real time regarding the security status of cargo in transit. One approach to achieve this objective is to integrate electronic identifiers into the sealing devices used on trailer and shipping container doors, or alternatively on cargo items (e.g. in the case of auto-carriers). This will either require the sealing device to also contain a GPS tracking and communications unit, or it will require an RF link between the seal and the tracking unit on the truck. The former approach implies the use of relatively expensive devices (US$250 or more) on all containers and trailers, which is likely to meet with some resistance from industry. The latter alternative can be implemented by integrating an active RFID transponder with tamper detection capability into the seal (at a cost of US$20-100), as well as linking an active RFID reader to the GPS tracking device of the truck. This will have the benefit of permanent installation of the active RFID reader in the truck rather than the need to install and remove the tracking device for each trip. It will however also present specific challenges, as a diverse set of GPS tracking devices are currently deployed on truck fleets; not all of these will have the built-in capabilities to allow communication with peripheral equipment like active RFID readers.

D. Passive RFID

The proposed solution requires the need to automatically identify trucks moving through checkpoints, which will include the depot of departure, weigh bridges along the route, parking areas at border posts, customs gates and the depot of final destination. While ANPR (automated number plate recognition) can be used for this purpose there is no way that an ANPR system can determine if a number plate that is recognized is genuine or counterfeit. The same would apply to special purpose placards carried by certified trucks to distinguish them from non-certified vehicles.

Passive RFID has found wide application in automated vehicle identification applications in recent years, and holds several benefits over alternative autoID technologies:

- It can be read at longer ranges compared to barcodes and at higher speeds (up to at least 200 km/h), allowing detection of vehicles in normal traffic situations;

- The shorter read range compared to active RFID ensure accurate identification of specific vehicles moving through specific lanes;

- The ability to store additional information on tags makes it possible to provide information about the status of the vehicles without requiring online checks, and can also support a higher level of authenticity by storing encrypted codes.

For these reasons passive RFID will be the most suitable technology to be used for the identification of vehicles at checkpoints. At the border it will be used for to identify vehicles entering the border area, allowing the automated channeling of compliant and non-compliant vehicles to different areas, to ensure that no vehicle passes through the customs gate without the associated documentation being processed and cleared, and to ensure that only the same vehicle as identified on the pre-declaration is allowed to pass through upon the presentation of a specific set of documents. In addition to its use on vehicles RFID tags can be attached to customs documents as means of automated detection that the documents were processed at that point and also to verify that critical information was not changed between the points of pre-declaration and final clearance.

VI. Proposed System Process Flows

In this section a brief summary is provided of the required system process flows to implement the proposed cross-border management concept, as shown schematically in figure 2 below. The assumption is made that the relevant customs authorities offer the alternative of Green Lane treatment to certified operators who are following a set of standard best practices for cross-border consignments.

Consignors will equip trucks with passive RFID tags mounted either on the windshield or on special purpose placards. In the case of containerized freight electronic seals will be used. Waybills submitted to customs will carry either a 2D barcode or an RFID tag containing a summary of the consignment (identity of certified consignor, customs codes applicable to goods, truck registration number, seal number, driver passport number, route and border post identifiers). All these fields will be submitted to the relevant customs authorities as part of electronic pre-declarations. In the case of goods falling into high risk categories as determined by customs an additional active RFID device enabled with GSM or satellite communications as described above will be used to seal and track the consignment.

While the consignment is in transit a summary of status information will be dispatched to the customs authority at agreed time intervals – this will include the GPS location of the truck, the status of the sealing device and any deviations from designated route that have occurred.

Upon arrival at a border the truck will stop at a screener lane where the truck identity and seal identity and status will be checked automatically and where the driver must present the waybill as well as his passport to a close-range scanner. Once the consignment has been identified its tracking status as well as the status of the consignor will be called up by the system and the rules of the Customs Risk Engine will be applied to determine whether the consignment is regarded as representing any form of customs risk.

If all items presented correspond to the pre-declaration, the tracking status does not include any exceptions and the consignor is currently in good standing, the consignment will qualify for Green Lanes treatment. The system will randomly select a low percentage of compliant consignments for physical inspections. The consignment will then be channeled by a set of booms to either directly move to the customs gate for final clearance of to a parking area to be subjected to customs inspections. At the customs gate a similar automated check will be performed before the truck is allowed to pass through. The important aspect is that for a fully compliant consignment the clearance process will not require the driver to leave the truck and will delay the truck by a maximum of a few minutes before clearance is granted.

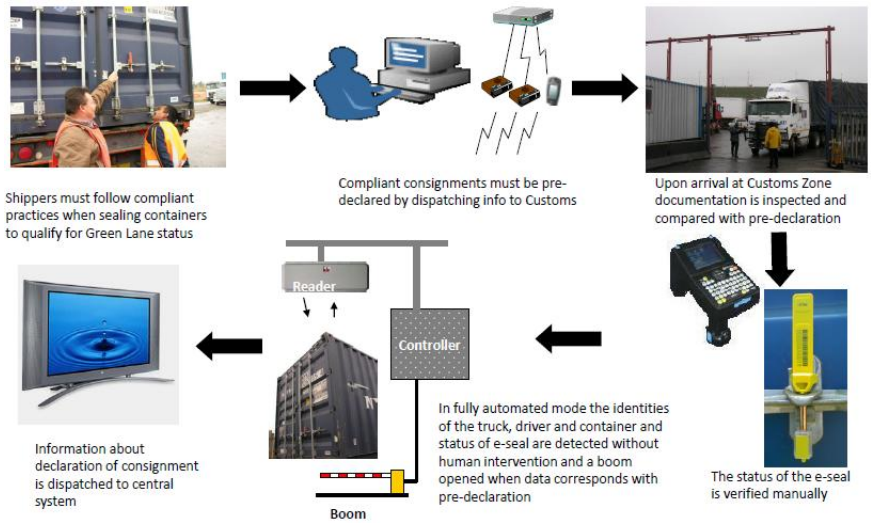


Fig. 2. Process flow for the management of consignments in transit

Should a truck be non-compliant, or compliant but selected for inspection, it will be guided to a parking area. A customs official equipped with a handheld terminal (with the required scanning capabilities) will be designated to perform the inspection and the current standing and historic track record of the consignor will be used to determine the priority that it will receive. As part of the inspection the official will be required to scan the identifiers on the truck and the waybill to ensure that there is complete traceability of the inspection process. Should the inspection require the opening of a sealed consignment the customs official will scan the seal and its status before it is removed, and replace it with a similar customs seal after completion of the inspection. A complete record of the inspection and its outcome will then be submitted to the customs system via the handheld terminal. If the consignment is found to be compliant it will be channeled back to the customs gate for final clearance.

The customs system will keep records of all consignments processed through the border; in the process it will build up a record of the level of compliance of all consignors – this information will be used to update the current standing of such participants, and will determine the level of inspections applicable to such players in future.

VII. Cost-Benefit Analysis

In order to determine whether the cost-benefit will be positive is it necessary to make an estimate of the expected costs of deployment of the proposed system.

Firstly the cost of capital deployment at border posts is estimated. The figures in in Table IV are used as basis for the cost estimation. In order to cover the major routes used by the approximately 6,000 trucks doing regular trips in Eastern and Southern Africa it will be necessary to equip approximately 20 border posts [6]. The capital outlay will include civil works to implement screener lanes, installation of scanners in customs lanes, handheld terminals and desktop scanners used by officials, as well as custom software and integration to field equipment. The estimate comes to a figure of approximately US$320,000 per border post or US$ 6.4 million for all border posts.

For the outlay required by consignors provision is made for three different options:

1. Using only passive RFID and only handheld scanning of documents, vehicles and seals;

2. Using only passive RFID but adding permanently installed readers at exit and entry lanes to automatically detect trucks upon dispatch and arrival;

3. Using passive RFID on trucks and documents, active RFID in seals and custom GPS/GSM tracking devices for remote monitoring of consignments.

The number of independent consignors that will be interested in certification is estimated at maximum 500 (according to SACBTA industry figures there are only about 160 transporters of significant size operating between South Africa and neighboring countries). The average cost per consignor for the three options identified above comes to US$36000, US$56000 and US$70000 respectively, with total industry capital outlay of US$18 million, US$28 million and US$35 million for the three options.

TABLE IV. Capital Outlay for System Deployment

Cost of Capital Outlay at Border Posts:	
Number of border posts	20
Number of hh terminals per border post	12
Number of desktop scanners at each border	6
Number of customs lanes per border post	4
Cost per equipped customs lane	$25 000
Cost per handheld terminal	$5 000
Cost of computer equipment	$10 000
Cost of civil infrastructure to screener lanes	$100 000
Cost of software and integration	$50 000
Total capital outlay per border post	$323 000
Total cost for all border posts	$6 460 000
Cost of Capital Outlay at Consignors:	
Number of certified consignors	500
Number of trucks	6000
Number of e-sealing devices	20000
Number of handheld terminal per consignor	2
Number of desktop scanners per consignor	2
Number of exit gates at consignor	2
Cost of passive RFID tag	$2
Cost of e-seal	$50
Cost of active reader/GPS/GSM unit	$1 000
Cost per RFID equipped gate at consignor	$10 000
Cost of desktop scanner	$500
Cost of software integration per consignor	$25 000
Capital outlay RFID manual scanning only	$36 024
Capital outlay RFID manual and automated	$56 024
Total capital outlay per consignor	$70 024
Total capital outlay RFID manual scanning	$18 012 000
Total capital outlay RFID manual and automated	$28 012 000
Total capital outlay for all consignors	$35 012 000

If the above costs are compared against the estimated benefits it can be seen that, taking the most expensive option (option 3 above) and the most conservative cost benefit (i.e. assuming no increase in traffic but improved profitability per trip) the proposed system should pay for itself in approximately 6 months. This does not even consider the reduced long term investment in trucks as well as the positive spin-offs to the regional economy resulting from a more efficient transport sector.

VIII. Conclusions

In this paper we provide evidence of the large cost to the regional economy of sub-Saharan Africa resulting from inefficient cross-border operations. It was shown that the cost to transporter alone runs into hundreds of millions of US dollars annually, excluding the much larger cost to the mining,

manufacturing and retail sectors due to long and unpredictable delays in the delivery of freight consignments.

We argue that the inefficiencies experienced at border post are largely the result of lack of reliable information to enable customs authorities to make accurate decisions, as well as a lack of transparency that allows customs officials and truck drivers to become involved in illegal practices. A new improved cross-border management concept is proposed that leverage currently available technologies to make available much richer data sets to enable customs to accurately distinguish between compliant and potentially non-compliant consignments arriving at a border. This proposed system will use a combination of passive RFID, active RFID, GPS tracking and handheld technology to capture audit trails of freight consignments, in the process improving both the efficiency and security of cross-border operations.

The cost-benefit analysis demonstrates that even for the most conservative scenario the proposed new system will pay for itself within 6 months; under a more optimistic scenario the costs of deployment will be recovered by the transport industry within a matter of weeks. Of much more importance is however the positive long term impact on the regional economy to restore sub-Saharan Africa to its rightful position in the global economy. Future work will concentrate on the implementation of a practical pilot study to verify if the envisaged improvements can be achieved in practice.

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