Using RFID for Risk Mitigation and Location Assuredness of High-Value Goods

Gabriel G. Nasser
I.T. Director
TJS dmcc
Dubai, U.A.E.

***Abstract*-We present a natural application of Radio Frequency Identification (RFID) technology for tracking and tracing *high-value goods* (HVG) in general. We cover in more detail such an application in the jewellery industry where large volumes of jewellery items are affixed with *tamper-evident* tags and scanned daily, thus lowering the risk for inventory shrink and deviation. Further, such application provides granular visibility on a daily basis where, traditionally, inventory counting sessions are manual, inaccurate, labour-intensive, and too infrequent to provide concrete value.**

Finally, we offer insight into an innovative financial model made possible by such an application. The model offers new opportunities for funding and alleviating the burden and risks of high-value inventory endured by trading partners in the industry. The model also offers new possibilities to financiers for providing gold jewellery consignments to retailers, wholesalers, and manufacturers, as a competitive alternative to traditional *gold loans*.

I. Introduction

In recent years, the use of RFID [1] has steadily gained popularity in several areas including retail, aerospace, defence, manufacturing, baggage handling and tracking, among many others [2, 3]. In fact, RFID has touched almost every single industry with applications ranging from human tracking to on-shelf availability, from backroom management to real-time delivery tracking, and from e-pedigree to electronic proof of delivery [2].

Adoption of RFID technology has been helped by the backing of major players in respective industries and by the focus on creating clear and comprehensive standards that cover all aspects of the technology including identification schemes such as *Electronic Product Code* (EPC), specific reader technologies such as *listen-before-talk* [6], application specifications such as *Application Level Events* (ALE) [4], open standards for interoperability such as *EPC Information Service* (EPC-IS), data exchange definitions such as *Physical Mark-up Language* (PML), and service discovery specifications such as *Object Naming Service* (ONS) [5].

Tagging of goods in the supply chain occurs at all levels of the logistics and operations hierarchy, including transportation vehicles, containers, pallets, cases, individual items, and anything in between. Usually, the decision of *what* to tag is dictated by the business case, return-on-investment calculation, budget constraints, and other operational factors. As an example, at the current cost of a certain item-level tag it may not make sense for a chewing gum manufacturer to place a tag on each individual packet, but it may do so for each case containing several dozen packets.

One specific use for RFID, namely *track-and trace*, is a basic and natural application of the technology. Tracking and tracing involves the tagging of an item and recording its movement throughout its life through the supply chain. Each movement of the item is an *event* that occurs at a specific and discrete time and at a specific and discrete location. Typically, events are recorded by receiving radio signals from an RFID tag that is affixed to an item as it passes through the field of a reader. The data from the signal then is collected and is aggregated by a central system that maintains information about the latest event and the history of all events pertaining to that item.

In subsequent sections, we present briefly a sketch of a business case for tracking and tracing HVGs in general, and gold jewellery inventory more specifically. We also show that improvements to the model provide benefits that extend beyond gains in time-consuming and labour intensive operations such as inventory counting. Finally, we describe a new financial model that has emerged from such an application and that promises to curb the risk of investment in the gold jewellery industry, from manufacturers, to wholesalers, and finally retailers.

II. High Value Goods

Carrying, distributing, and selling HVGs impose several burdens on the supplier, distributor, and retailer. The cost of such goods is, by definition, high and so the effects of shrink can be prohibitive. There are further *hidden* and *indirect* costs associated with HVGs that derive from different sources, some of which are described below.

1) *Insurance*. It is almost imperative for companies to insure their HVGs since a few missing items can translate into great losses. Insurance is expensive and most often is not in favour of the insured with respect to the terms and conditions.
2) *Handling*. Expensive goods are usually fragile and they may require special handling or specific environment conditions to prevent damage.
3) *Safe storage*. Storing HVGs must be performed under controlled conditions and must be performed by few individuals or parties with special privileges.
4) *Secure transportation*. HVGs are least secure when in transit. It is not uncommon for deliveries to arrive at

their destination either partially missing or to not arrive at all. Proper transportation of HVGs requires careful planning and execution, or the use of security transportation experts to undertake the task. All such methods incur significant costs.

Tracking and tracing HVGs is a straightforward and invaluable application and its business case is reasonably insensitive to the cost of implementation and the recurring cost of tags. The business case covers tracking and tracing from the point of manufacture to final delivery to the customer to provide end-to-end visibility of the goods at all pertinent points in the supply chain in order to reduce shrink and control operations in a more scientific manner. Benefits of end-to-end visibility in this case include

1) The ability to measure *actual* time in transit against the *predicted* or *expected* time and to make adjustments accordingly. When actual time in transit is significantly *higher* than the expected time in transit then an inspection of the route or the process is warranted; similarly, when the actual transit time is significantly *lower* than the expected time then perhaps the expected time is exaggerated and should be lowered accordingly.
2) The capacity to detect the disappearance of goods early and to limit the *search* or *investigation* area to a minimum. Ideally, detection points should be placed between *trust boundaries*, such as between departments or divisions, between outgoing shipment departments and the transportation provider, and between the transportation provider and the receiving department, to name a few. Such a setup enables quick identification of mishandling and prompt assignment of responsibility, both key elements in mitigating theft.

III. Gold Jewellery

A. Overview

Gold jewellery is a special case of HVG and presents a particularly challenging problem due to the following constraints.

1) Items have varying degrees of size, shape, and form and thus it is hard to attach RFID tags to them, let alone establish a simple and comprehensive guideline for tagging jewellery items. Further, not all items can be tagged due to shape constraints. For example, it is impossible to attach a loop tag around an open bangle.
2) Gold jewellery may be subject to extreme cleaning conditions involving chemicals, steam, and high heat. Therefore, we require the use of resistant RFID tags to withstand similar conditions.
3) Gold jewellery is very adverse to RFID because it is primarily made of metal and the dense nature of retail displays compound the problem further.
4) The design of the tag to be placed on gold jewellery must take into account aesthetic appearance to a high degree so that it does not spoil the jewellery displays.
5) The handling and packaging of gold jewellery can promote a high number of damaged tags.

The gold jewellery industry is an old trade and, unfortunately, it has maintained many of the old techniques for accounting of inventory and verification. Predominantly, stock counting is still performed manually in many parts of the world and remains inaccurate, time- and labour-intensive, and error-prone at best. Recently, within the past 10 years, several companies have adopted barcode technology to help improve their bottom line, but with little to no benefit. In fact, in some situations, it has led to an increase in time spent performing the task, due to the introduction of barcode label application and data entry.

The introduction of barcode technology in the jewellery sector brought some advantages but, unfortunately, not the intended ones. The following disadvantages are still prevalent, especially among medium to large retailers who have adopted barcodes.

1) Items must still be scanned one at a time. This change has introduced more inconvenience since it requires the operator to orient the tag so that it is facing the scanner eye and then to scan it. Further, it is an investment in equipment that provided no gain in efficiency. It is fair to mention, however, that barcode systems help to reduce user entry errors and help to automate data capture which are otherwise time-consuming tasks.
2) Barcode labels are not affixed securely to the items. This very fact has created confusion and a false sense of security among the adopter of the technology. The reasoning was that since a barcode was scanned then it gave the impression that the item is present. It is often the case that the barcode label was left behind and the item was nowhere to be found.
3) Barcode technology did not lead to faster stock takes. At best, in typical stores, stock taking occurs every six weeks on average, which is too infrequent to provide any tangible benefit. A full stock count can require the addition of extra staff and the closure of the shop for the duration of the process which may result in lost sales. The entire process can span a whole day and sometimes can last up to 3 days, depending on the shop size. This approach does not scale well once a company expands beyond a few retail locations.

In the next subsection, we show how RFID overcomes many of the shortcomings of barcode implementations in the jewellery space.

B. Applying RFID

Specific RFID technology was developed, tested, and implemented to address the above problems by focusing on each individual area separately as follows.

1) By its nature, RFID does not require *line-of-sight* to scan the tags, which is an inherent limitation of barcode technology.
2) Special RFID tags were developed to provide a *tamper-evidence* feature [10], so that the tag leaves electronic or physical evidence of misuse, such as attempting to re-attach the tag to an item of lesser value, for example. This characteristic indicates, with a high degree of certainty, the presence of an item if scanned.
3) With the use of high-performance RFID technology specifically designed for the high-metal and dense jewellery environment, it is possible to perform reliable and extremely quick stock takes as often as daily. Table I provides some time measurements that were collected over 6 months across 3 shops of differing sizes.

The data collected in Table 1 relates the number of pieces to be scanned and the number of readers used to the average time required (in minutes and seconds) to achieve a count of 98%, 99%, and 99.99% scan of the total items, respectively. The data clearly shows that a major portion of time is spent scanning a minor percentage of the items. Reducing this time requires focusing on the last stages of the search process and iteratively improving it.

Improvements include coordinating staff movement throughout the activity, for example. It is noteworthy mentioning that the measured time involves not only the scanning time but the total time taken to perform the inventory, which includes movement of staff, opening of cabinets, removing items from the safe, etc. We also conclude that adding more readers does not speed up the process of counting the remaining 2% of the items, but only contributes to slightly speeding up the initial count.

C. Traditional Financing

Producing, trading and selling gold jewellery requires significant investment of capital largely due to the high value of the raw material itself, namely *gold*. Financing in the jewellery industry typically is given in the form of a *gold loan* [8], granted by a financial institution, e.g. a bank, to a market player, e.g. a retailer or a wholesaler. However, since the loan is in the form of gold rather than in actual currency value, it exposes the industry to several problems, some of which we list in Table II [7].

TABLE I
INVENTORY SCANNING AVERAGE COMPLETION TIMES

Avg. Items	No. of Readers	Avg. Time to 98%	Avg. Time to 99%	Avg. Time to 99.99%
3,000	1	12:30	15:40	23:40
5,000	3	25:00	28:30	42:30
8,000	3	41:00	59:30	88:00

All times are in minutes:seconds

TABLE II
PROBLEMS OF TRADITIONAL GOLD FINANCING

Problem	Description
Exposure to the international gold price	Wild fluctuations in the gold price on the international market hurt financiers and wholesalers and retailers alike. Fluctuations are highly sensitive to political and socio-economic changes.
Requires original cash margin	Prior to taking a loan, retailers and wholesalers must deposit a sum of cash to protect the financier against future adverse movements of the price of gold.
Subject to variation/call margin	When the price of gold rises beyond a certain level, the financier requests the wholesaler or retailer for additional funds to cover the increase in the price of gold since the loan was given in gold form.
Requires significant capital investment	The jeweller requires a large capital base to build his stocks. This results in that investment appearing on the jeweller's financial balance sheet.

The effects on the industry are devastating and, after sharp increases in the gold price as were the cases in September 1999 (see Fig.1) and May 2006 (see Fig. 2), several small retailers declared bankruptcy and medium-size and larger retailers were forced to reduce their stocks dramatically or close some of their retail locations, or both. Wild and continuous fluctuations in the gold price also have a negative effect: in 2006, we observed several spikes of $100 or more. In the aftermath, the industry spends several years to restore to a healthy state.

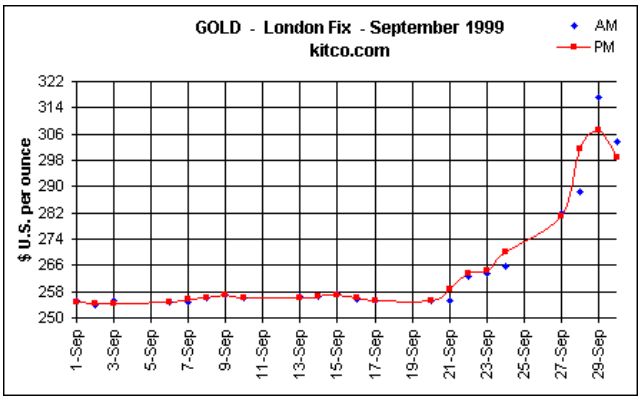

Fig. 1. Price of gold during September 1999.
Note the sharp increase towards the end of the month.

Fig. 2. Price of gold during 2006.
Note the peak at $732/oz. in May, up by more than $220/oz. from the beginning of that year.

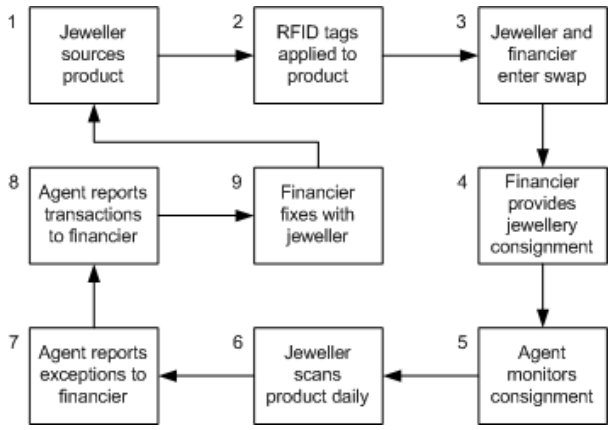

Fig. 3. New Financing Model.
Courtesy of The Jewellery Store dmcc. PCT International Patent pending.

D. New Financing Model

To address the inefficiencies and the risks associated with gold jewellery financing as presented in the previous section, a new model is needed that can address the shortcomings on a structural level. This new model assumes that the current setup of gold jewellery financing is structurally unstable and it attempts to create a new one where the fluctuations of the international gold price do not harm the financiers, the wholesalers, or the retailers [9].

The approach uses RFID technology as its core component. Using Fig. 3, we explain the main parts of the model. Firstly, a gold jeweller sources product from her favourite suppliers for her retail locations (1), then the product is affixed with *tamper-evident* RFID tags and the relevant information is entered into a system of record under the supervision of an independent monitoring agent (2). Once the product is tagged and verified by the agent, the jeweller and an interested financier enter into a swap transaction, whereby the jeweller passes title of her jewellery to the financier and the financier, in return, provides her with an equivalent value in gold ounces at the then prevailing price of gold (3). In (4), the financier places the swapped gold jewellery, which he now effectively owns, on consignment at the jeweller's retail location provided that the product is scanned daily with secure RFID equipment under the remote supervision of the independent agent (5). Since stock scans occur daily (6), the agent's responsibility is to track exceptions such as an item's tag not being scanned on a particular day, to report them to the financier, and to launch an investigation into the matter (7). The agent is also responsible for reporting normal business transactions, such as sales and inter-location transfers, to the financier on a daily basis (8), who in turn fixes the amount of gold sold on that day with the jewellery at the then prevailing gold price (9). Once settlement has been made, the jeweller may source further product and the cycle repeats (1).

The model is intricate and has several levels of detail. We only show an abridged and simplified version that exposes some of the abstractions and simplifications that were considered during its development. We established that a major deficiency of the existing model – one that relies heavily on hedging and high-risk - was that it has been in place for over 2 centuries [8] and it *seemed* to work adequately.

The heart of the setup dictates that the gold jewellery remains the ownership of the financier at all times, up to the point of sale. This requirement can only be achieved if we assign a *custodian* who monitors the inventory until the jeweller settles with the financier. It is quite clear that the only tool so far able to make it possible to meet that requirement is RFID. Along with the use of tamper-evident tags and high-performance equipment, it is possible to scale without real limits and to eliminate much of the human factor involved in security and assuredness.

IV. Conclusion

We showed that recent innovation and progress in RFID transformed the jewellery industry by introducing new operational efficiencies and process improvements.

We presented an innovative financing model, enabled by the RFID technology, which reduces the risk and cost associated with trading and selling gold jewellery. The model has been implemented and proven in real stores and is currently operational. We believe that this model can extend beyond the gold jewellery industry and that it is applicable to high value industries in general.

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