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Use of Sensor Embedded Products to Tackle Fraud in Warranty Service for Remanufactured Products

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Abstract: The issue of warranty fraud in remanufactured products has been addressed in recent literature. This paper addresses the issue of warranty fraud arising from the warranty service agent. The study aims to examine false maintenance service claims in the consumer electronics remanufacturing sector, and examines strategies available to the warranty provider to tackle said fraud. Discrete event simulation is utilized to contrast how the use of sensors may mitigate maintenance claim overcharging fraud by comparing relevant fraud statistics with the previously existing system. The study showed that the sensor embedded scenario was able to preemptively stop more frauds.

Keywords: Reverse supply chain, Fraud, Remanufacturing, Warranty.

1. Introduction

The aim behind remanufacturing products is to repair and replace damaged and out-of-date component parts and to restore the product back to as good as new condition. Remanufacturing is the end-of-life (EOL) process that involves the most amount of work, but in exchange goods that have been remanufactured tend to have higher quality and reliability compared to repaired and reused products. From a performance standpoint, a remanufactured product may be considered to be equivalent to a brand new product; however, due to a host of reasons (subjective or real), the consumer may not perceive that as being the case. Realistically, a consumer is frequently unsure about the quality of a remanufactured product that is to be purchased and is therefore unable to judge how capable the product is at rendering service, which might lead to a decision to opt-out of buying it. Due to these kinds of preconceptions held by consumers, manufacturers often search for market mechanisms, such as warranties, that might provide assurance about the reliability of remanufactured products [1].

In many cases, the job of performing warranty-related services is done in-house, other times they are outsourced to third-party service providers. With a host of parties involved in the warranty service chain, each with their own goals, motivations, and competing interests involved the likelihood of fraud being committed by one or more is inevitable. Remanufacturing has seen a rise relatively recently and as a result, a number of considerable problems still negatively affect the remanufacturing industry such as warranty planning, product pricing, and product quality issues [1-3]. A number of these issues were addressed by first reviewing the extant literature on traditional manufacturing systems and as such it was judged that reviewing literature related to dealing with fraud in the new product industry would produce similar results.

2. Literature review

In recent years, there has been a shift in research interest towards environmentally conscious manufacturing. This was partially due to practical interests driven by government legislation and a shift in the public's consciousness over concerns regarding the depletion of natural resources. Several subsequent review papers demonstrated the building interest in this area [4-5]. Being a relatively new field, certain issues may not be quite as prevalent due to a lack of product volume (such as fraud); which also presents an opportunity to strike at the problems before they appear.

Warranty has in the past been used as a tool for competitive marketing. Many manufacturers and researchers have explored a host of ways to make a product more appealing by experimenting with warranty policies by doing things such as adding additional services, extending the periods, offering favorable terms, etc. [6]. Many of the same issues have been tackled more recently in the remanufacturing sector as well [1], [7].

The most prominent types of fraud are insurance frauds, financial frauds, and business frauds and the type of frauds that they deal with are distinct and may offer clues as to how to solve remanufactured related frauds. The study of such frauds has been a topic of interest among researchers in recent years [8], [9].

A literature review compiled by [10] examined literature related to how fraud is dealt with in other industries. The review, in their concluding statements noted many process similarities and drew a number of parallels. One of which is that the warranty service process for remanufactured products bears a resemblance to the service chains for the other industries examined in the review. This factor also extends to any potential fraud mitigating structures.

In recent studies, theoretical frameworks have made use of embedded sensors in electronic products to procure andanalyze specific data in order to assist in warranty management. The use of such sensors to address issues in consumer electronics products has been suggested in the past to deal with issues both at EOL ([3] for washing machines) and even during a products life ([7] for laptops) thus suggesting that sensor embedded products (SEP) could be an effective way of catching fraud.

Based on the literature review we can see that fraud is still a prevalent issue in the consumer product industry. However the majority of extant literature focuses on new products, little research is focused on frauds pertaining to remanufactured products. While a number of techniques (such as game theory, [8]) have been used in the past, many models consider fraud to be one of the events and do not incorporate factors such as prior history and party motivation. Additionally, the trend of sensor implementation has proven to be useful in solving other problems, and literature shows a few instances that show it has potential in dealing with this particular fraud scenario. These points influenced the direction and methodology followed in this study.

3. System description

A discrete event simulation model was constructed with a number of service agents (SA) each submitting multiple claims to a warranty administrator (WA) who functions as an intermediary between the SA and WP. As described in figure 2, the claim validation process runs parallel to the warranty servicing process.

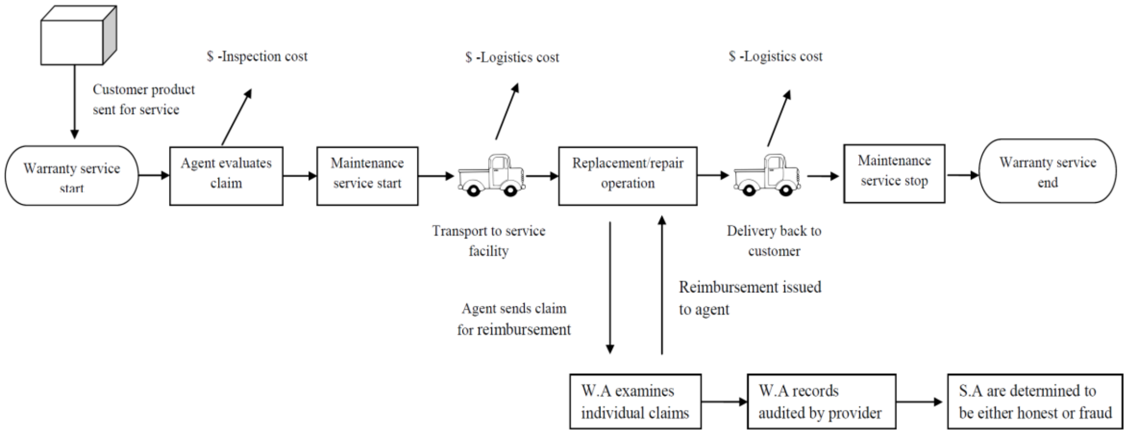


Figure 2: Warranty servicing with claim validation

A collection of decision variables affect the result of decisions at each stage of the claim validation. In a regular system (RS), when a warranty claim is made by the customer, it is the SA's responsibility to first verify that the customers claim is true and conduct the required maintenance activities to fulfill the warranty contract. The losses that the remanufacturer suffers due to fraud take many forms. Loss in productivity occurs when SA's are attempting to rectify claims that are fraudulent while delaying the processing of true claims on hold. In the model, productivity loss time is calculated by determining the time between receiving the faulty claim and the service completion time. The SA sends the WA's a claim to seek reimbursement for services rendered and barring any noticeable discrepancies, the SA is reimbursed. The remanufacturer additionally conducts a number of audits in order to verify the nature of the claims. The paper recreates two possible scenarios to study aspects of fraud, which are listed below.

3.1 Proposed model scenarios

The flow of the claim investigation process in regular systems is depicted in figure 3. The inspection structure of the sensor embedded systems is more complex than those of the RS's. Using the information provided by the sensors, the claim validation processes can be planned differently. In RS's fraud is caught during the second stage of investigation.

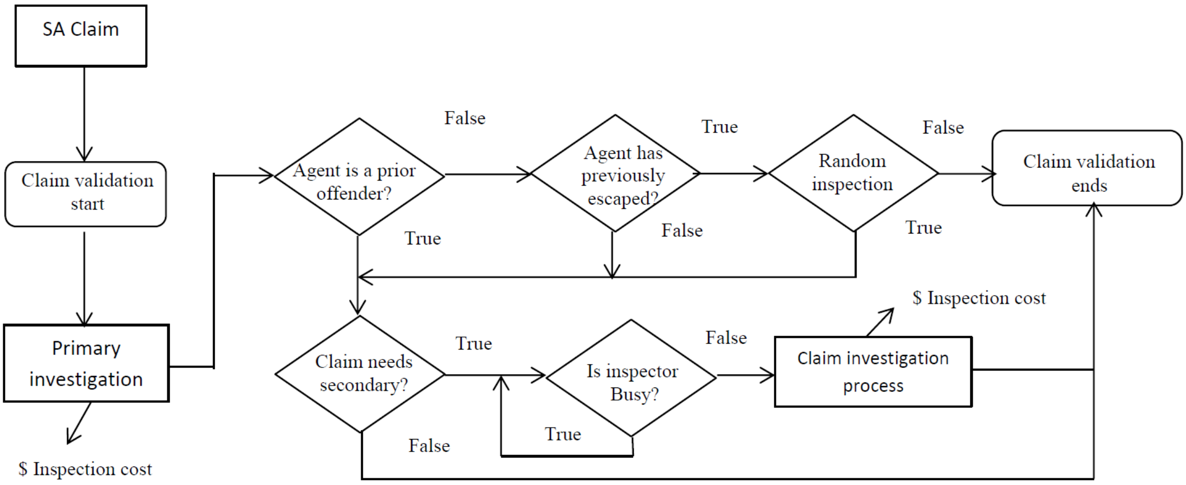


Figure 3: Warranty service investigation process

In a sensor embedded system, fraud can be caught (and later confirmed by the investigator) before reaching this stage. While the sensor can assist in fraud detection, we do not (initially) assume that it can supplant manual investigation. The flow of claims in an SEP system is depicted in figure 4.

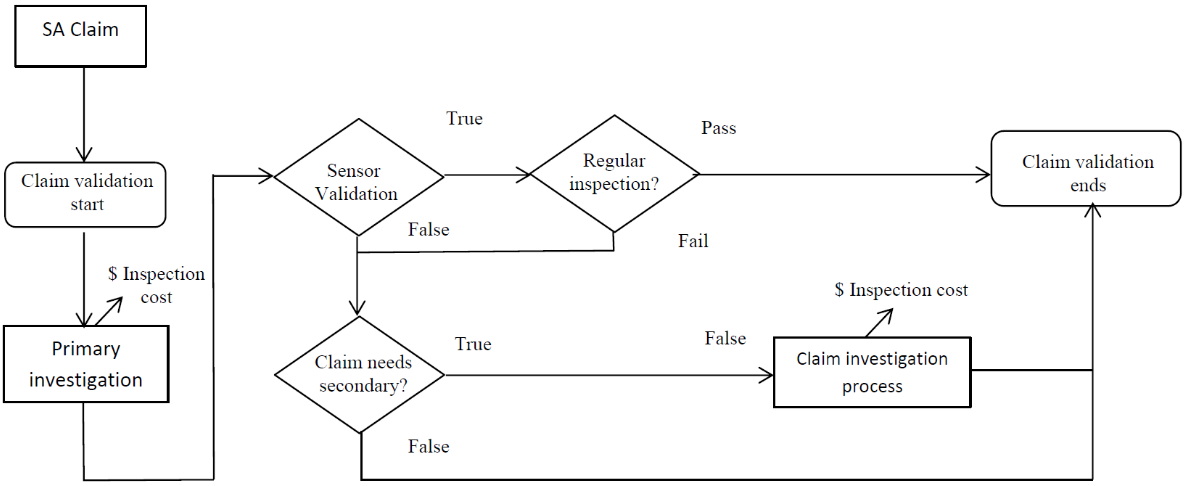


Figure 4: Warranty service investigation process (sensor embedded)

The costs that are considered for this model include the revenue costs and the costs to the remanufacturer. Costs to the remanufacturer include the costs for audit (Inspection costs for primary and secondary inspection) as well as logistics costs (related to maintenance activities emanating from a fraudulent claim) as well as other related costs (such as service costs for maintenance activities). Additionally, when a fraud is committed, we consider that fraud (a dollar amount) to be a loss to the remanufacturer (cost of uncaught fraud). In the case of SEP it would be necessary to include the cost of sensors as well. The sources of revenue that are considered are primarily from the cost of penalizing fraud. This is not to say that many other sources of revenue do not exist (sales, additional warranty and out of warranty service costs, etc.), but are not considered for this model.

3.2 Model and settings

This section expands upon the various decision variables and model assumptions that the simulation scenario follows in order to accurately recreate a remanufactured product warranty service supply chain. These include the simulation models inputs/outputs, process block functions, and how fraud will be modeled.

3.2.1 Claim modeling

(a) Customer claims

We assume that issues (problems) that result in a maintenance/refund claim being submitted by the customer to the service provider fall into one of two broad categories.

(1) Superficial problems
These encompass issues the customer has with the product that are purely "surface level" and do not affect a product's functionality. These problems can be real but are most often subjective. (Example: Scuff marks on a phone casing, "warping" of display screen, etc.).

(2) Functionality problems
These encompass those issues that affect product functionality. (Example: A dead phone battery, nonfunctional touch screen, etc.). Based on the level of repair required, the service agent may judge that a replacement is the less expensive option.

If a corrective maintenance strategy is chosen and the failed components are replaced, the material cost associated with the replacement of the components is added to the overall maintenance cost. Finally, logistics costs are also taken into consideration within maintenance costs.

(b) Warranty administrator Claims

The WA is in charge of handling claims from the SA. Based on prior statistical data, they exercise their judgment in determining if a SA claim is either true or false. In other words, the WA serves as a check on behalf of the WP, to ensure that the SA acts honestly. Warranty agent claim data details the value of reimbursement paid out to the SA in exchange for their warranty services, which include inspection, repair, and replacement costs. Under normal operating conditions the claims from the WA are taken at face value by the WP.

(c) Service agent claims

Service agent claim data details the amounts that the SA charges for their warranty maintenance services they perform on behalf of the warranty provider, which include inspection, repair and replacement costs. Under normal operating conditions the claims from the WA are taken at face value by the WP.

3.2.2 Fraud modeling

(a) Service agent fraud modeling

The SA submits multiple claims to the administrator. The claims can be either true or false (fraudulent). The probability that a fraud occurs is outlined in table 1.

Table 1: Factors that influence service agent fraud

Factors	**Rationale**
Previously evaded	If the SA has previously committed a fraud without being penalized, it is assumed that the agent will be more bold (more likely to commit fraud) the next time they make a claim
Previously penalized	If the SA has previously committed a fraud and was penalized, it is assumed that the agent will be more careful (less likely to commit fraud) the next time they make a claim. Additionally, the size of the said penalty will also bias if the decision to commit fraud
Total number of claims	It is assumed that the probability of fraud increases proportionally with the number of claims (especially if the S.A has never been penalized in the past)

(b) Other fraud

The literature notes that there are instances of customer-driven and warranty administrator fraud [10]. However, for this paper, we do not consider fraud originating from other sources.

3.2.3 Maintenance and other operations

(a) Service agent maintenance operations

We consider the number of warranty claims by customers to a service agent for a small-scale electronic appliance (cellphone). The cellphone has an average lifespan of 4 years with a warranty length of 14 months. We consider that maintenance operations carried out by the SA to fall into one of 2 categories

(1) **Repair operations**

These operations involve those operations where faulty components are replaced by the SA. In this case, it would be either be a battery replacement or a smart screen replacement. A more standard inspection for wear and tear is also considered as part of this operation

(2) **Replacement operations**

These concern cases where replacing the item would be less cost/ time-intensive than repair. This could be due to a number of reasons such as multiple components failing at the same time, and the product is too old such that getting replacement parts proves too difficult.

(b) Claim investigation process

(1) Auditing process assumptions

For the purpose of the model, the auditing process is assumed to take place over two stages. The first stage functions as a general review of all SA metrics, from efficiency to customer satisfaction. This stage is considered to be a mandatory part of the audit, and cannot be skipped under any circumstance. It is assumed that the probability of discovering fraud is less likely if only this stage is cleared.

The second stage of the audit is referred to as the secondary inspection which is a focused audit that makes note of the basics of the service rendered (service expenditure, labor cost, prior record of claims, etc.). This stage distinguishes itself from the initial stage in that it is a more detailed investigative audit process that may involve multiple queries between the investigator and the SA to determine that the claim can be verified. The secondary inspection is reserved for cases where there is cause for concern that a fraud has been committed.

(2) **Secondary inspection assumptions**

The secondary inspector is assumed to be prone to error. This, therefore, leads to 4 separate outcomes of the investigation outlined in table 2 (Null Hypothesis (Ho): After inspection, the claim is not found fraudulent)

Table 2: The outcomes of an inspection

Decision	**Truth=fraud**	**Truth= not fraud**
Not fraud	Type II error	Correct
Fraud	Correct	Type I error

In addition, it is assumed that multiple inspectors are being employed with varying levels of experience and competence. To represent this variability, multiple inspectors of differing capabilities are considered. The secondary inspection can be triggered by a number of different factors which are outlined in table 3.

Table 3: Types of secondary inspection

Factors	**Rationale**
Random Inspection	Occasionally, claims may be randomly selected to go through a secondary fraud inspection.
Inspection triggered due to suspicions	If certain parameters (such as a suspicious number of claims within a fixed time period or if claim value is higher than the projected costs) deviate from standard values, then this might trigger an inspection of the SA
Inspection triggered by lack of scrutiny	If a number of SA claims are accepted without a need for inspection (either because the claims show no warning flags or if they were never selected for a random inspection), there is a chance that an inspection is triggered(this probability increases as more claims go unreviewed by the secondary inspectors)

(c) Sensor behavior assumptions

Based on work by [11] and [7] we assume the following relationship (figure 5) between the cost of sensor implementation and the confidence (probability) that the sensors accurately determined a fraudulent claim. The aim of sensor implementation is to free up auditors to look at claims that are more likely to be fraudulent and reduce the need to look at a random selection of claims.

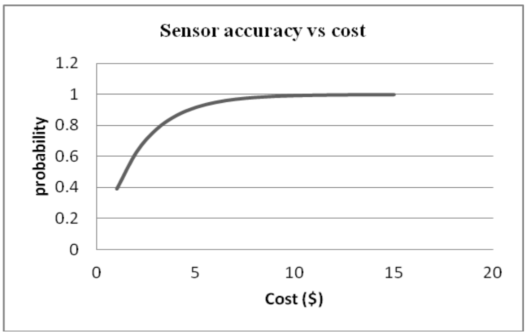


Figure 5: Relationship between sensor accuracy and sensor costs

(d) Other Model Assumptions

Some other model considerations were made

- The claims from a SA (assuming multiple) are audited and reviewed separately
- The time between audits exceeds the time it takes to process a single audit
- The secondary inspections are assigned to inspectors on a random basis (preference given to shortest queue)
- There are a fixed number of SA's under the warranty contract (we do not assume that are any hiring's or firings)
- We do not assume an unusual number of claims arising from product design defects (and other natural causes) only those of a fraudulent behavior
- We assume only frauds of an overcharging variety from the SA, i.e. we do not assume the implication of other fraudulent types

4. Case example

4.1 The remanufactured product and warranty service

The remanufactured product that is under consideration is the Samsung galaxy smartphone (refurbished/remanufactured), the products details as well as related component costs are listed in table 4.

Table 4: Specifications of the Remanufactured product

Product description	**Details**
Product name	Samsung galaxy s7 refurbished/remanufactured
Date of release(original)	2015
Product lifespan	4 years
Warranty length	14 months
Retail cost	$ 599

This information is used to generate the cost of each individual product claim (for both the SA and WA), which varies depending on which of the maintenance operations being is carried out (table 5).

Table 5: Maintenance costs

Assumed costs	**Dollar amount($)**
Standard product inspection cost/product	$5
Replacement screen	$69
Replacement battery	$30

Table 6: Costs from inspections

Assumed costs	**Dollar amount($)**
Cost/audit	5
Cost/inspection	15

Table 6 covers costs (from the audit inspection) that were employed in this simulation model (rounded up approximations from [7]). Along with cost, the other key factor of consideration is the various time-dependent variables. These may include the different inspection process times as well as arrival rates (frequency of fraud audits). Table 7 summarizes the process times related to the claim audit. We do not consider maintenance and associated logistics times (only the related costs). Process time does not assume the lag (lead time) between when the decision to audit is made and when it actually starts, i.e. assumes the validation begins instantaneously.

Table 7: Simulation process times

Assumed times	Distribution	Parameter(s), Time scale
Primary audit	Triangular	(0.2,0.5, 0.7) ,Hrs
Secondary inspection	Triangular	(0.5,1.0,1.5) ,Hrs

4.2 Fraud modeling

The SA has a number of factors that affect its decision making. The service agent's past history with the investigation and audit process would bias their future decision making. To that end, the effect of past outcomes on future decisions has been summarized in figure 8. Additionally, it is assumed that the selection criterion for random inspections also does not remain the same for all cases.

The functions that determine the probability in each case are dependent on a number of factors (as summarized in figure 6). As claims are submitted for review, it is assumed that earlier claims have an impact on later claims. For e.g. the service agent may submit false claims earlier on and be caught which will bias later claims to be more true than false. The reverse is also assumed to hold true (i.e. uncaught fraud causes later claims to be more false than true, shown in figure 7(a)).

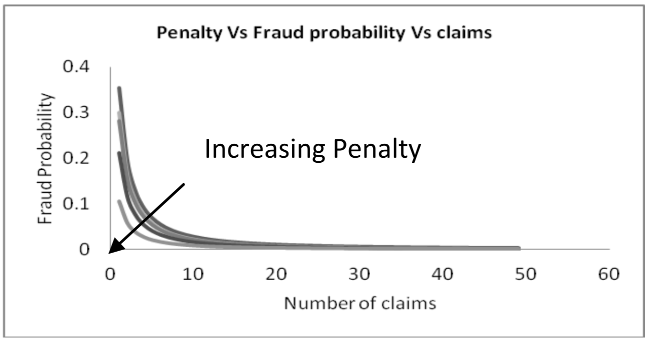
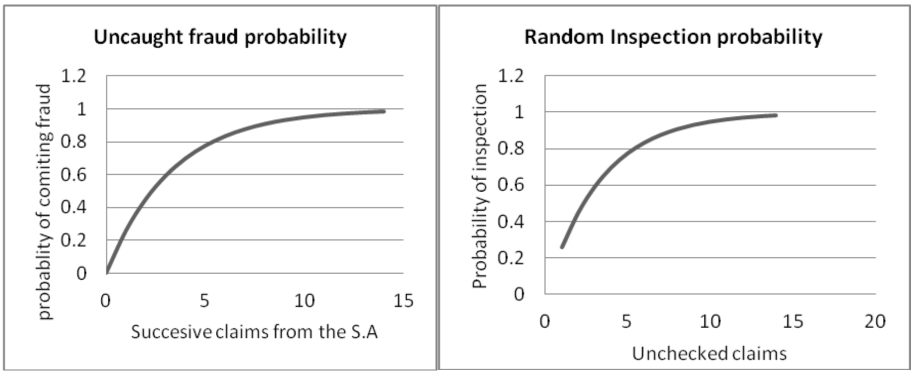


Figure 6: Relationship between fraud probability, penalty value, and number of claims



(a) **(b)**

Figure 7: (a), (b) Graphical representation of uncaught fraud probability and random inspection as.

Having discussed the behavior of the service agents with respect to fraud and investigation process, next, the behavior of the inspectors with respect to fraud and investigation process is modeled. As outlined in the previous section it is assumed that investigators will have some amount of variation. Their distinguishing features are their individual success rates at correctly detecting fraud In addition to accounting for the probability of not detecting actual fraud (Type II error), the probability of falsely charging an agent (Type I error) is also accounted for.

Discrete event simulation was used to model the RS (base) and SEP systems. Arena 16.1 simulation software (Rockwell, Austin, TX, USA) was used for the modeling process. To validate the models, they were run by assigning extreme values to variables and corresponding performance measures were observed with these runs. For example, if the probability of detecting fraud is increased nearing to 1 (perfect inspection) the number of subsequent frauds being committed by the SA decreases dramatically. Similarly, if the inspection probabilities are set to be below 0.5, over time the probability of committing fraud increases over the simulation run for each service agent. The run length of the simulation experiments was 5 years. SEP systems and RS (non-sensor) were introduced, and the design of experiments study was explained.

5. Results and Discussions

5.1 Case Analysis

For the fraud model, the two scenarios were run with the inclusion of SA fraud. Over a period of 5 years, a total of warranty 10,325 in warranty claims are submitted by the consumers and received by the SA for warranty services, where 4,130 claims were battery related maintenance repairs, and 3,614 claims are smart screen related maintenance repairs which were reimbursed for $ 320,901 and $ 132,814 respectively by the WA. Additionally, 2581 claims resulted in full replacements.

For the model (for both the RS and SEP cases), experiments were carried out, and the data pertaining to the total profit, inspection cost, and fraud costs were tracked. Table 8 contrasts the difference between the base scenario and the SEP scenario by describing statistics pertinent to fraud detection and inspections.

Table 8: Fraud detection statistics

Service agent claims statistics	**Base Case (RS)**	**With Sensors (SEP)**	**Percentage improvement (%)**
Uncaught false claims	107	75	26
Uncaught false claims (only manual)	107	58	N/A
Uncaught false claims (with sensor)	-	16	N/A
Falsely charged	41	34	4.3
Caught fraud (from investigation)	68	64	7.5
Total general audits	850	750	-
Total claims flagged by sensors	-	109	N/A
Total inspection	406	379	6
True claims (from investigation)	279	267	8.3
Average time in system	15.91846	14.4901	3.2
Number of SA claims that fools Sensors	-	19.5	N/A
Number of true SA claims that are flagged by sensors	-	81	N/A
Approved claims	741	651	0.5
Max Queue length (primary)	3	2	50
Max Queue length (secondary)	5	3	33

The data indicated that the use of sensors significantly reduced the cost of the inspection process. There were certain parameters that did not follow this pattern, for example in RS; the inspection cost for the simulation period was $5377 while this rose to $5692 in the SEP systems. Table 9 presents the average values of the performance measures mentioned above, as well as the total cost for both systems.

Table 9: Fraud detection statistics

Measure	**Base system($)**	**Sensor embedded system ($)**
Inspection costs	5377	5692
Uncaught fraud costs	3307	2625
Total costs	12435	12067

Table 10: Pairwise *t*-test results for mean difference.

Measure	**Mean Difference($)**	**p- Value**
Inspection costs	-315	<0.0001
Uncaught fraud costs	682	<0.0001
Total costs	368	<0.0001

Results (The results of the pairwise t-tests, including mean differences and p-values, are presented in Table 10) show that sensor embedded system shows a statistically significant improvement over the base scenario with respect to fraud detection. A number of correlations between different factors were also observed.

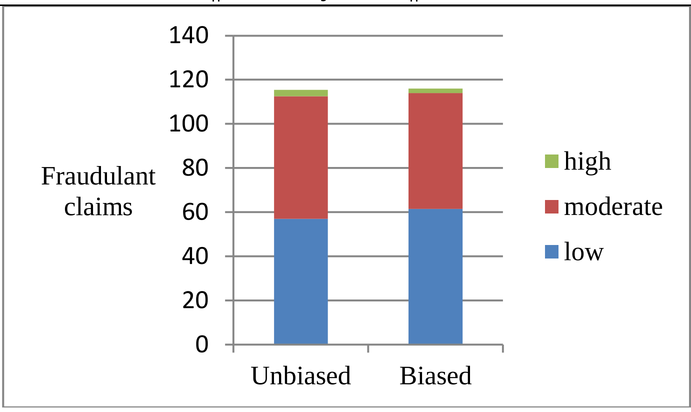


Figure 8: Number of fraudulent claims by category (sensor embedded)

If subsequent frauds are considered to be unbiased by previous claims we see that while the propensity for committing higher types of fraud exists (High, moderate and low refer to the size of the individual fraud), penalty cost also likewise increases. If however, we consider that there is a link between previous claims and subsequent fraud, we see the number of larger sized frauds decrease (figure 8). There also exists a positive correlation between inspection cost and the total cost.

In summary, it is possible to use sensors to if not to just to combat, but also to better track fraud. Sensors also provide additional benefits because they can be used to gain an economic advantage in a closed-loop supply chain system.

5.2. Limitations and extensions

Some of the prominent limitations ones are listed below.

- Fraud from tertiary parties could not be conceptualized , additionally the WA-SA relationship requires further modelling
- In a realistic scenario, frauds do not occur in isolation. A model addressing customer and customer related frauds would be beneficial
- A lack of available public data proved problematic and certain parameters needed to be approximations
- Sensors implementation as a way to curtail SA fraud was addressed but methods to stop WA fraud was not fully explored

6. Conclusion

Fraud is a sometimes overlooked issue in both manufacturing and remanufacturing environments. This paper described some of the literature surrounding the issues of fraud and warranties in the remanufacturing sector. The use of discrete event simulation was found to be effective in modeling the actions of fraudulent actors over longer time horizons. Finally, an approach to mitigate fraud against the warranty provider was proposed. Based on the results the objectives of this paper were either fully or partially addressed. The SEP system generally yielded positive results.

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