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Tackling Substitution Fraud in Remanufactured Product Warranty Service

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Abstract: Issues of fraud in the service industry have been well examined in recent literature. One area that has not received significant attention is issues related to fraud detection and prevention in the area of remanufactured product warranty. Fraud may arise from many sources, each posing unique problems. This paper limits its focus to the issue of remanufactured product warranty frauds arising from the customer, more specifically those related to the consumer electronics remanufacturing sector. The paper reviews strategies available to the remanufacturer to manage such fraud. A case example is considered, where a discrete event simulation model is used to examine how a sensor-embedded product may be used in mitigating part substitution fraud. The case example is shown to preemptively identify and mitigate frauds. The methodology could be used in practice to deter these and other types of fraud.

Keywords: Fraud, Maintenance, Remanufacturing, Sensor embedded system, Warranty

Introduction

The goal of remanufacturing is to bring a product to a new product's condition, if not in appearance but at least in performance; however, the consumer may still harbor misgivings that may lead to a negative perception of remanufactured products. This manifests itself as uncertainty in the mind of the consumer regarding the apparent quality of the remanufactured product. Remanufacturers have turned toward marketing as a possible solution to provide additional assurance to the consumer through the use of tools such as product warranties. Warranty servicing is a multi-layered system that involves multiple groups, each with their own goals, motivations, and competing interests working together. The lack of cohesion in vision and conflicting private interests make it a fertile ground for fraud to appear. Fraud appears in many forms, one example is when a component part that is not within the manufacturer's warranty period, is placed in a product that is within the manufacturer's warranty period, with the goal of being repaired or replaced at a loss to the remanufacturer [1].

This category of fraud is not confined by the scale of the product, as it appears in both the automotive industry and in the consumer electronics sector. This paper improves upon existing methods of fraud prevention and detection by considering the implementation of sensors to the products. Several metrics such as the number of frauds that go unchecked, the total cost of inspection, revenue lost from fraud, and number of falsely charged claims are used to determine if sensor implementation was successful in deterring fraud. The study uses discrete event simulation to conclude that sensor implementation has generally positive benefits when it comes to the issue of fraud detection and prevention.

Literature review

The field of environmentally conscious manufacturing has produced many research papers that are of interest in setting up this study. A number of review papers illustrate the rising interest in this field, and while at the present time certain issues may not be prevalent, steps should be taken preemptively to deal with problems that will grow with time, such as fraud [2], [3]. It has been shown that it is important for manufacturers to balance their sales strategies in response to the introduction of remanufacturing [3].

Warranty has in the past been used as a tool for competitive marketing. Many manufacturers have explored what makes products more appealing and by experimenting with warranty policies by doing things such as adding additional services, extending the periods, and offering favorable terms [4]. Strides have been taken to identify the level of cost the manufacturer must incur in order to fully satisfy the consumer's warranty expectation [5]. There is evidence that more expensive complex products involve more extended decision-making, thereby enhancing the probability that the warranty could play a significant role [6]. The majority of the extant literature was focused on warranties with respect to the new product industry. Many of the same issues have been tackled in the remanufacturing sector as well [7]. A case study considered a two-dimensional warranty policy with the objective to maximize consumer confidence and minimize the cost to the remanufacturer for a remanufactured product in washing machines [8].

Warranty fraud is a significant problem affecting motor vehicles and other consumer products having multiple components that are the subject of a warranty. These frauds are typically only between the manufacturer and the service agent (SA). The concept of warranty fraud in the remanufacturing industry was introduced and reviewed relatively recently [9]. An early study focused on the issue of SA remanufacturing fraud, and its effect on the warranty provider (WP) by modeling the problem using discrete event simulation [10]. In the same paper, they also discussed possible methods to alleviate fraud. Similarly, the issue of remanufacturing product fraud was also modeled using game theory [11], where they established the relationships between various factors such as fraud size, inspection frequency, and penalty amount. A study by Pandit and Gupta [12] first outlined the issue of remanufactured warranty fraud originating from the customer through the use of a discrete event simulation model and served as the starting point for this study.

There are methods and systems for obtaining and analyzing data using embedded sensors in electronic products for warranty management. The use of such sensors to address issues in consumer electronics products was first proposed to address issues both at EOL [13] and later extended to during a product's life [14]. This suggesting that there may yet be other areas where sensor embedded products (SEP) could be useful, including the problem of fraud. Sensors have many possible applications that may be useful in combating warranty fraud (Table 1).

Table 1: Sensor application in warranty service

Sensor Data	**Sensor data application**
Warranty start time	If the product is out of warranty
Product history • Product environment data • Product usage history (customer) • Products Maintenance service history (Customer)	Application • If the warranty has been voided due to alteration or damage • If product has been used inappropriately violating terms of service

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. Previous remanufacturing fraud studies have focused on fraud from sources such as the warranty service agent, warranty administrator, and product parts provider but these studies have neglected a very important entity in the warranty service chain, namely the customer. Additionally, the trend of sensor implementation has proven to be a boon in solving other problems and literature shows that it has potential in dealing with fraud. These points influenced the direction and methodology followed in this paper.

Fraud overview

Other than the direct costs such as revenue loss, warranty fraud has many indirect consequences which may overall have more damaging consequences. Repair data received from service agents are often used as a tool for research and development. Manufacturers use information acquired from field data to address product quality issues and take corrective action. This idea works well in principle but if this data include fictitious or claims of dubious nature, separating real quality problems from fraudulent billing can be difficult. As a result, unreliable product quality feedback may delay corrective actions [15]. This is an escalating problem as it might also result in product recalls which are unnecessary and highly expensive and reduce the effectiveness of predictive maintenance. This may affect decision-making on a large scale, as the manufacturer might terminate profitable products that are incorrectly assumed to be loss-making. Warranty fraud can also affect the warranty provider's reputation and damage its brand. This is the case, for example, when customers are wrongly denied warranty service or receive poor service due to fraud [15]. While many studies assume the customer being on the receiving end of the fraud, in this instance we try to examine how the customer attempts to defraud the other parties.

The occurrence of customer driven fraud is not confined to just the warranty period as it very often takes place even after the warranty has expired. Fraudulent warranty claims may also be associated with products that have never been purchased by the customer. Customer fraud typically relates to cases where a customer tries to have a repair or replacement done although there is no warranty coverage. This can be the case when the warranty has expired, the customer has damaged the product, or the service action is not covered by a warranty. Usually, the fraud done by a customer is limited to one or a few cases per purchased product, although large-scale fraud also exists. A number of different instances of warranty fraud are compiled in Table 2 [16].

Table 2: List of frauds originating from customer

Victim of Fraud	Aim	Methodology
Warranty provider	Refund/replacement	Unjustified return or replacement of item that is not faulty or is a fake
	Service cost avoidance	Getting out of warranty products repaired under warranty
	Extra products or earning	Claiming and reselling parts or replacement items
	Service level improvement	Claiming better service than being entitled for

This paper examines a specific fraud scenario, namely the case of component substitution fraud. This fraud manifests itself in many ways, for example, having bought multiple numbers of similar products at different times (e.g., LED light bulbs or tablets), the customer may try to utilize the warranty of the newest product to have the old one replaced. In a similar way, defective parts in an out-of-warranty product can be changed to an in-warranty product and claimed under warranty. If the equipment or the proof of purchase does not have a serial number or the parts used are not serial number tracked, it is hard to control whether the proof of purchase relates to the faulty product. The same applies to large installations that consist of multiple equipment installed at different times and that contain in-warranty and out-of-warranty products. In this situation, gaps in the warranty provider's entitlement process or data can be used to obtain service also for out-of-warranty products. In this paper, we attempt to model an instance of substitution type customer-driven warranty fraud for a consumer electronic product.

3.1 Description of the system

Based on relative importance the different parties can be sub divided into 3 categories which are described in Table 3 (Assumes that the remanufacturer is the primary warranty provider). The primary parties refer to those that are chiefly involved in the warranty service chain, the secondary parties assist the primary parties in warranty operations, whereas the tertiary parties have no direct role in the warranty operations, but they are invested in the performance of the warranty service.

Table 3: Parties involved in a warranty servicing scenario

Category	Parties
Primary	Remanufacturer, Service agents, Customers
Secondary	Parts manufacturer, sales channel, Warranty administrator
Tertiary	Leasers, Inspectors, Logistics companies, Underwriters & Insurers, Government, Shareholders

Component substitution fraud mainly involves the primary parties, in that the consumer is the fraud's perpetrator and the service agents (and by extension the remanufacturer) are the victims. In a typical warranty service system, when a product is rendered nonfunctional, it is inspected to determine the cause of failure. The information about any such failure is transmitted to the service personnel who conducts the required service operations; for example, replacing the failed component or components. After this process, failed products are transferred to the service facility. After the maintenance process takes place, the products are brought back to working condition. Once the maintenance service operations are complete, the products are returned to the customers. The generalized activity flow chart for all types of warranty maintenance is shown in Fig 2.

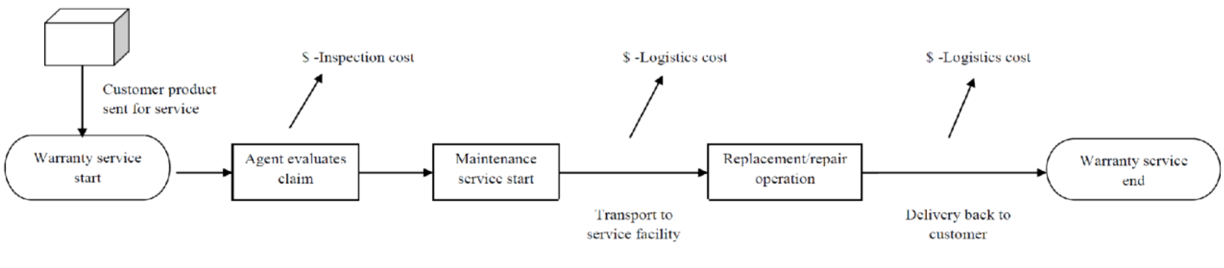

Figure 2: Warranty service operation for products

The above case presented assumes that the claim is true and that the customer is acting in good faith. However, when introducing the concept of fraud into the scenario, it is assumed that for certain cases that at least one component in the product to be serviced originates from another product that is no longer under warranty. The service of such a product would violate the warranty agreement between the customer and the remanufacturer. In addition to the extra service cost incurred, there would also be additional inspection and logistics costs to account for. The next section describes two simulation scenarios that were considered to model the problem further.

Methodology

This section discusses the process flow and model parameters that are pertinent to this study. The warranty service is assumed to be performed by a single service maintenance agency. For regular claims, service begins when the item/product under warranty is submitted in-person to an authorized service center/ retailer (customer service). Customer service responsibilities include the return merchandise authorization process (RMA), the entitlement to verify the customer's eligibility for warranty repair within the warranty period. Upon maintenance completion, the product is returned to the customer (return channel).

4.1 Basic flow chart

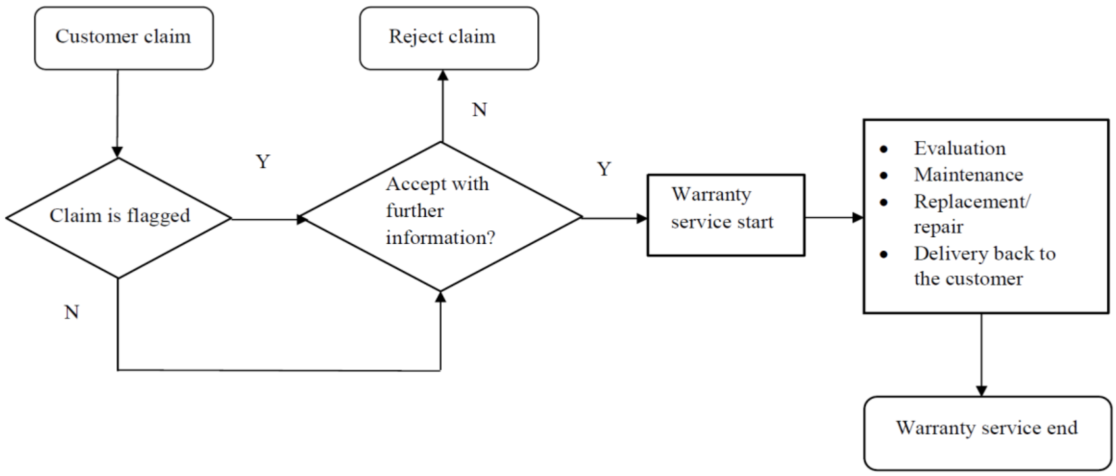

Figure 3: Basic flow chart of warranty claim

Fig. 3 gives the generalized process flow of warranty customer claims. Customer (or customer service) passes on the claim to the SA after claim entitlement is conducted to ensure that the product is in warranty. The maintenance activities under consideration fall under either the repair or replacement such that when repair cost exceeds the replacement cost the then product is replaced instead. The decision to investigate a service claim from a customer after passing through the entitlement process is assumed to take place on a random basis (random inspection) additionally we consider the inclusion of certain warning flags that might additionally result in an inspection. For the purposes of the study, it is assumed that the claims (both fraudulent and true) pass through the RMA and entitlement processes without issue, as the study focuses on what comes after (the claims investigation). Table 4 below outlines the various factors that affect the customer claim, investigation process, and sensor behavior (for sensor embedded systems)

Table 4: Simulation model factors

Category	**Subcategory**	**Assumptions and justifications**
Factors that push the customer into committing fraud	Prior fraud history	It is also assumed that a customer's prior experience with the investigation process will bias them either toward or away from fraud. For e.g. if a customer gets away with committing a fraud once then the probability that they will commit fraud next time increases. Conversely, if a customer is caught, then the probability of committing a fraud next time is similarly reduced
	Confidence in the investigation process	If the customer is able to commit fraud in multiple successive instances without being caught by either the audit or secondary inspection, the probability that the customer would commit fraud would increase with each successive escape

Factors that affect claim processing	Prior criminal record	The prior record of the customer (only of caught fraud not committed fraud) will influence the investigator's decision to accept the claims as true
	Warning flags	There are certain indicators that might set of warning flags when a claim is examined. (an unusual # of claims in a fixed time period)
	Inspection error	There are a number of reasons that the inspection claims can be imperfect. Human error can occur due to a number of reasons, though most often inexperience or negligence
Factors that affect Sensor behavior	Claim data on record	As the sensor can provide better records (such as dates, times, and location data) it will be more likely to accurately determine if the submitted claims are true.
	Sensor damage	There is always the possibility that failure of a sensor may occur, either deliberately or by accident, and it is often not easy to determine if it was done maliciously to cover up fraud, or just an accident

4.2 Simulation model scenarios

The study makes use of discrete event simulation to model customer-driven fraud. The model was simulated using Rockwell arena software, the input to the simulation model are customer claims, which arrive at a rate governed by distribution functions. The logistics costs were assumed at a fixed rate per trip (to and from the repair center), while the inspection cost was assumed on an hourly basis. We consider the following two cases for our research.

4.2.1 Scenario1 –Regular systems

In a regular system (RS), when a warranty claim is made by the customer, it is the service agent's responsibility to first verify that the claim is true and conduct any services to fulfill the warranty contract. There exist built-in systems to catch substitution frauds. For instance, in electronic products, each part possesses serial numbers that can be cross-checked in order to determine if the component is from the same product or series. This process is fairly time intensive and cannot catch all types of substitution fraud (components that may be used across multiple product series such as batteries might be substituted between products of different generations without the SA being any wiser). In cases of fraud, we consider multiple forms of cost to the remanufacturer. Productivity loss occurs when service agents are trying to rectify claims that are fraudulent while putting true claims on hold. In the system, productivity loss time is calculated by determining the time between receiving the faulty claim and the service completion time. Maintenance costs include the costs that are incurred as a result of inspecting the product failure. Since 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.

4.4.2 Scenario 2 - With sensors

In sensor embedded scenarios (SE) we assume that sensors can make up for some of the shortfalls that exist in regular systems. To highlight this effect, we consider the existence of human error in the model and as such consider claims to be reviewed by multiple inspectors that may fall into one of 4 categories, each with slightly different process times and fraud detection capabilities. The model assumes that the customer's past fraud history will have an effect on the decision to commit fraud in the future. For instance, the model assumes that if a customer has been previously successful in committing fraud, the truthfulness of the next claim will be different from if they were previously caught. In addition, sensors are assumed to retain data on which parts have been replaced in previous inspections which theoretically should prevent a repeat of fraud using the same product. In theory, sensors should be able to shorten the time required to verify that all the components from the same product as well as prevent additional substitution scenarios (the battery example). In addition to costs that are incurred in the RL, we also assume the cost of sensor implementation. A product recall is a request from a manufacturer to return a product after the discovery of safety issues or product defects that might endanger the consumer or put the maker/seller at risk of legal action. We consider the possibility of fraud resulting in an eventual product recall. This will allow us to make the determination if the cost of sensor implementation is worth any potential fraud-catching benefits. The next section outlines the basic assumptions that were made to simplify our model.

4.3 Simulation model assumptions

The simulation model simplifies many of the complexities of the warranty service chain in order to narrow the study's focus on the fraudulent claim investigation process. The assumptions that have been made are as follows.

- The warranty service starts from when the defective product is brought to the local service center, assumes that customers are able to clear RMA online
- The product (supposedly) experiences either a partial failure (Intermittent) or complete failure (Nonfunctional)
- Maintenance activities are primarily corrective in nature
- Does not assume a product with any extended warranty
- Assumes that some amount of disassembly will be required for all claims
- More than one instance of fraud ends the WP obligation to the customer (benefit of the doubt)
- If found fraudulent, the customer is charged for transportation costs
- Assumes that the SA and WP are behaving honestly

4.4 Model formulation

4.4.1 The investigation processes

The claims investigation process can occur due to one of two reasons, the first being random inspection and the second being the existence of a suspicious claim resulting in an inspection. Fig. 4 below models the probability of a customer claim being selected for a random inspection, the factors that determine a claim to be suspicious were previously outlined in Table 4 (simulation model factors). The model makes an allowance for inspection errors (type I and Type II). The model also makes allowances for errors due to experience (job experience).

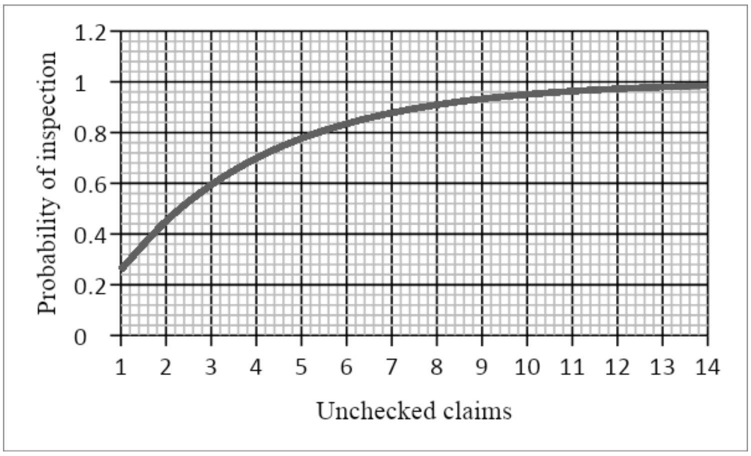

Figure 4: Probability of random inspection

4.4.2 Warranty Claims

a) Normal claims

A single customer may raise zero, one, or more warranty claims over the warranty period. White goods (i.e., refrigerators, ovens, and other large household appliances), consumer electronics, and watches, for example, typically have no or a limited number of warranty repairs during their warranty period. More complex products like cars or large industrial installations will have a higher number of warranty claims over the warranty period. Customer warranty claims occur in an uncertain manner over time. The cumulative count of claims follows a stochastic (unpredictable) counting process over time [16].

b) Fraud Claims

The underlying reasons for fraud are vast and complex, we attempt to model the issue of fraud from an engineering perspective, therefore we isolate the two primary factors (from an engineering standpoint). They both stem from the customer's confidence in the investigation process (Table 6).

Table 6: Factors that influence service agent fraud

Factors	Rationale
Previously escaped	If the customer has previously committed a fraud without being caught, it is assumed that the customer will be more bold (more likely to commit fraud) the next time they make a claim (Fig. 6)
Total number of claims	It is assumed that the probability of fraud increases proportionally with the number of claims (especially if the customer has never been caught in the past) (Fig. 5)

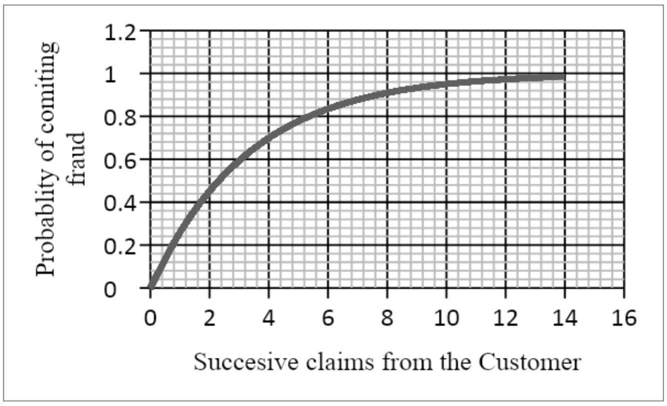

Figure 5 – Probability of customer committing fraud as a factor of the overall number of claims submitted

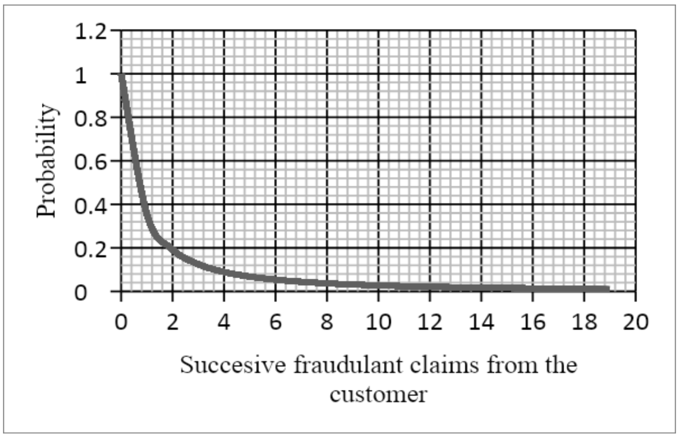

Figure 6: Probability of customer committing fraud after being previously apprehended

4.4.3 Fraud and logistics costs

There exist many costs that are associated with warranty service operation; this study focuses on those costs that pertain to/highlight the fraud-related aspect of this problem, Table 7 lists these costs.

Table 7: Costs pertaining to the model

Cost	Explanation
Logistics costs	These include the costs to transport the item from the customer to the maintenance center and back to the customer
Investigation costs	The cost of investigating the fraudulent claim
Uncaught fraud costs	Refer to the loss to the manufacturer in being defrauded which in this instance is equal to The cost of the component being replaced for free
Total Cost	The net cost to the remanufacturer

4.4.4 Sensor behavior assumptions

Based on previous research [14], [17], we assume the following relationship (Fig. 7) 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.

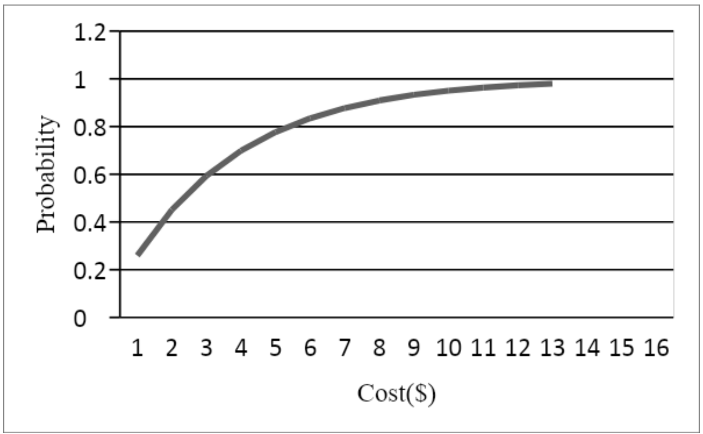

Figure 7: Relationship between sensor accuracy and sensor costs

Numerical example

We consider the customer warranty claims to a SA for a small-scale electronic appliance (laptop). The laptop has an average lifespan of 4 years. The warranty length is assumed to be 14 months. There is one component that is substituted (memory ram card). The data is presented in the form of the number of claims per month that the SA receives over the time period of 3 years (Table 8).

Table 8: Laptop warranty claims over 3 years

Month \total claims per month	Year 1	Year 2	Year 3
Jan	320	310	305
Feb	336	326	320
Mar	304	295	290
Apr	352	341	336
May	384	372	366
Jun	339	329	323
July	352	341	336
Aug	304	295	290
Sep	352	341	336
Oct	320	310	305
Nov	288	279	275
Dec	256	248	244

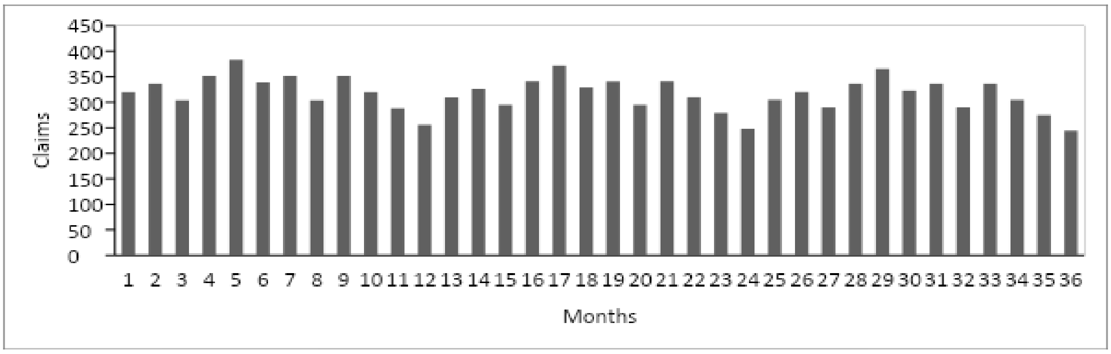

Figure 8: Number of monthly warranty claims over 3 years

Result and discussion

Experiments were carried out for both the RS and SEP scenarios, and the data pertaining to the total profit, inspection cost, and penalty and fraud costs were tracked. Table 9 contrasts the difference between the base scenario and the SEP scenario by describing statistics pertinent to fraud detection and inspections.

Table 9: Fraud detection statistics for laptop

Service agent claims statistics	Base Case(RS)	With Sensors(SEP)	Percentage improvement (%)
Uncaught false claims	1438.92	1140	25.797
Uncaught false claims (only manual)	1438.92	889.2	N/A
Uncaught false claims (with sensor)	-	250.8	N/A
Falsely charged	548.16	524.4	4.267
Caught fraud(from investigation)	913.6	980.4	7.454
Total general audits	11420	11400	-
Total claims flagged by sensors	-	1664.4	N/A
Total inspection	5458.76	5768.4	5.877(decrease)
True claims(from investigation)	3745.76	4058.4	8.294
Average time in system	35.071 hrs	29.10 hrs	3.164(decrease)
Number of claims that fools Sensors	-	296.4	N/A
Number of true claims that are flagged by sensors	-	1231.2	N/A
Approved claims	9958.24	9895.2	0.499
Max Queue length	2	1	50

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 normal systems; the inspection cost for the simulation period was $81738 while this increased to $86677 for the SEP systems. Table 10 presents the average values of the performance measures mentioned above, as well as the total cost for both systems.

Table 10: Fraud detection statistics

Measure	Base system($)	Sensor embedded system ($)
Inspection costs	81738	86677
Uncaught fraud costs	50274	39970
Total costs	189012	183747

Table 11: Pairwise *t*-test results for mean difference.

Measure	Mean Difference($)	p- Value
Inspection costs	-4939.8	<0.0001
Uncaught fraud costs	10304	<0.0001
Total costs	5264.2	<0.0001

Results (The results of the pairwise t-tests, including mean differences and p-values, are presented in Table 11.) 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. If subsequent frauds are considered to be unbiased by previous claims we see that while the propensity for committing higher types (in terms of cost) of fraud exists. If however, we consider that there is a link between previous claims and subsequent fraud, we see the number of larger-sized frauds decrease but likewise, the overall sensor value also goes down. There is a negative correlation between the sensor value and total number of frauds being committed. There also exists a positive correlation between inspection cost and the total cost. In summary, it is possible to use sensors to if not 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.

Conclusion

Results show that the sensor embedded system performed better than the regular system in terms of its ability to catch and deter frauds. There was a 25.8% decrease in the number of fraudulent claims that previously escaped, a 17 % decrease in the average time it takes to process claims, and an 18.6% decrease in total logistics costs. Based on our results, it was assessed that the cost savings from fraud and maintenance justified the implementation of sensors. The case example illustrates an overlooked problem in remanufacturing, and further exploration would prove beneficial in the promotion and confidence in remanufacturing.

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