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Remanufactured Product Warranty Oversight Fraud

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Abstract: The extant literature has examined warranty frauds in the new product industry quite extensively. However, fraud issues in the remanufacturing industry have only recently been explored in a meaningful way. Previous scenarios considered the primary parties in the warranty service chain (WSC) as possible sources of fraud. However, a number of unique opportunities exist for the secondary parties when it comes to fraud. This paper considers fraud originating from one of the secondary parties of the WSC, namely the warranty administrator. The paper models this particular fraud scenario using discrete event simulation, and explores a fraud mitigation scenario.
Key Word: End-of-life, Reverse supply chain, Fraud, Remanufacturing, Warranty.

I. INTRODUCTION

The recent surfeit of high-quality and low-cost products has gradually altered consumer behavior in unintended ways. This manifests itself as a trend where products are often disposed of before they actually spoil or fail. This leads to consumer goods reaching their end of life (EOL) in a much shorter time even though they are still functional. Environmental legislation has encouraged firms into moving away from disposal and more toward EOL strategies. By keeping waste to a minimum, these firms can reduce disposal costs, boost profits, discover new business opportunities, and protect and improve the state of the environment [1].

One such waste stream arises from the presence of fraudulent activities in the supply chain which not only generates excessive costs but also requires time and resources to manage. Frauds in the new product industry have been well covered in recent literature [2-4]. However, issues of fraud in the remanufacturing industry have only recently been explored. This study discusses the issue of fraud in the warranty servicing industry, namely scenarios in which the warranty provider (WP) can be defrauded by the other parties in the warranty service chain (WSC).

Previous studies considered scenarios which mainly limited to the primary parties in the warranty supply chain (Service Agent, Warranty Provider, and Customer). However, the secondary parties also have a role when it comes to fraud. These parties include the Warranty administrator (WA) and service channel. There are a number of unique scenarios that can exist mainly due to the position that these parties occupy in the WSC and responsibilities that they have. Warranty administrators are in control of service agents and their claims. They make decisions on claims to be approved and rejected and thus determine the value of the payment to be made to the service agent (SA) within the boundaries set by the warranty provider. Warranty administrators can also set up vendor master data and price data as the basis for service agent compensation. They can also make decisions to allow customers a refund, replacement, or repair as a part of the return merchandise authorization process. As representatives of the warranty provider, warranty administrators have the power to make decisions with financial implications. This power can also be abused. Additionally, since they are ostensibly in an oversight position there are no parties that are responsible for their regular oversight. For these reasons dealing with fraud from the warranty administrator poses a complex problem. The methodology that this study takes in analyzing this fraud is threefold, firstly the fraud is modeled in isolation, and the relationships between different decision variables are documented. Secondly, we build on the work of Pandit & Gupta [5], where the model is extended to include fraud from additional sources. Finally, the study considers the implementation of fraud mitigation.

II. LITERATURE REVIEW

The predominant areas where frauds can be found include health insurance, finance, and business sectors. Examining these types of frauds and how they are dealt with may offer clues as to how to solve frauds related to remanufacturing. A review of extant literature compiled by Pandit & Gupta [6] examined case studies that focused on the management of fraud in these industries. From this literature review, a number of conclusions could be drawn. One of which is that the WSC for remanufactured products, in particular, bears a great resemblance to the service chains for the other industries covered in the review.

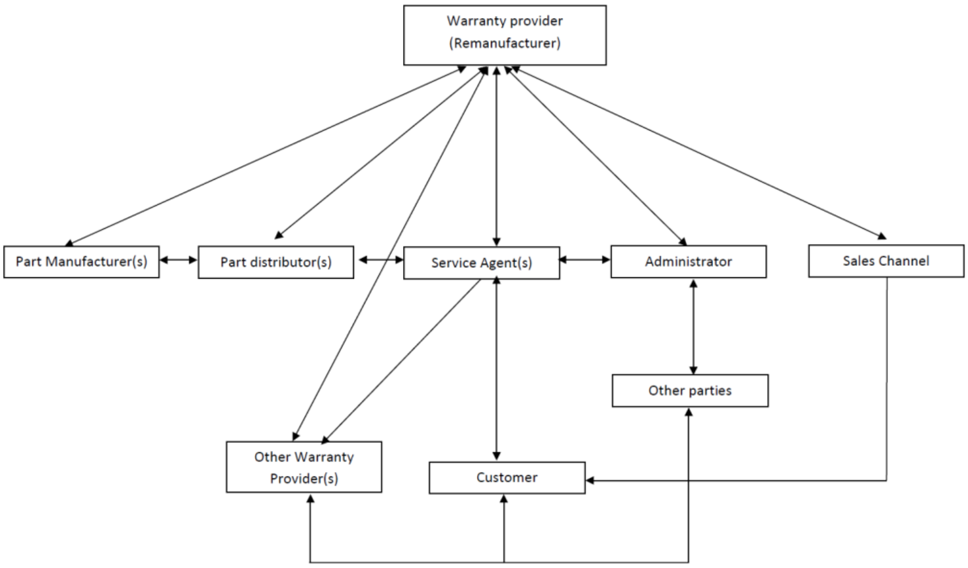

Figure 1: Information flow between key parties involved in a warranty servicing chain

Figure 1 shows the warranty supply chain for remanufactured products [7]. When a warranty provider offers a warranty on a remanufactured product to a customer, there are a host of other parties that are also involved in the service and thus may also be involved in any potential fraud. 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 a third party 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.

Dealing with frauds affecting the primary parties presents varying challenges. If the fraud source is the service provider, the audit of claims mirrors the same steps as for the review of claims in the health care and automotive field, and as such data mining and neural network methods would present the best way of dealing with such frauds. Similarly, if a service agent overcharges a claim, methodologies (anomaly detection) that are employed in the financial sector would assist in monitoring such frauds. If the source of fraud is the customer, the process of assessing the validity of a customer's claims is comparable to that of the health care and automotive industry and it follows that similar techniques would be effective.

The study considered numerous fraud scenarios and checked compatibility against various fraud modeling and detection techniques. It was determined that there was no "one size fits all" methodology that would properly encapsulate the problem. The merits of certain techniques, some that were not covered in the review were also noted. With regards to fraud modeling, game theory was shown to be useful in determining a party's optimum decision given the payoff (fraud amount) [8]. One study [9] used Nash equilibrium to contrast the optimum decision between the remanufacturer and the service agent for an overcharging warranty fraud scenario, and examined the relationship between fraud amount, penalty value, inspection cost and player risk. Discrete event simulation was also shown to achieve some measure of success in properly recreating the fraud scenarios and was also the most easily adaptable to fit new scenarios. This was shown to be the case in a fraud model that simulated service agent fraud [10]. The model was shown to be capable of being adapted to simulate customer driven fraud as well [11]. As with many other industries, the Internet of things shows the greatest promise in both fraud detection and prevention. Past studies have shown the usefulness of sensor implementation [12] in dealing with disassembly line quality issues and this would also extend to fraud detection (location data, temperature data, etc., which would assist in determining if a product was actually serviced and or used within recommended guidelines). A theoretical model was proposed by Pandit & Gupta [5], which considered the benefits of incorporating sensors into products would have with regards to reducing maintenance service times and inspection costs. A study by Pandit & Gupta [13], which used a neural network model in a remanufactured product warranty scenario, noted that the main hindrance to researching remanufactured product fraud is the lack of readily available data sets to conduct said research.

III. METHODOLOGY

Experiment model

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

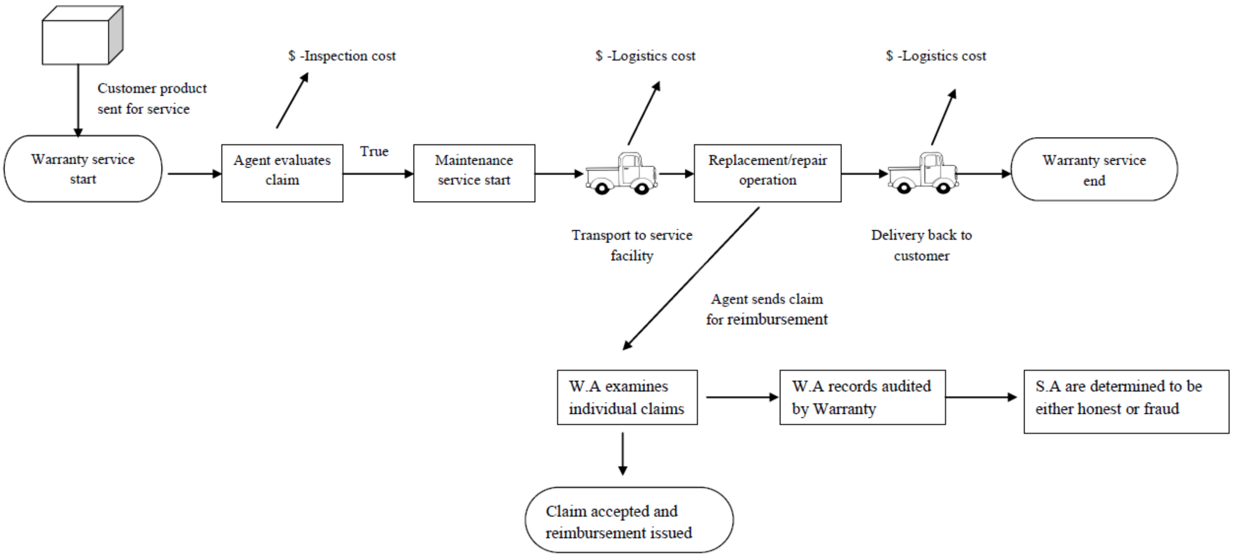

Figure 2: Warranty servicing with claim validation

A variety of criteria affects the outcome of decisions at each step of the validation process. In a regular system (RS), when a service claim is made by the customer, it is the SA's responsibility to first verify that the customer's claim is true and conduct any services to fulfill the warranty contract. In cases of fraud, we consider multiple forms of cost to the remanufacturer. Loss in productivity occurs when service agents are inundated dealing with false claims while putting actual 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. The SA sends the WA 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 proposes a number of possible scenarios to study aspects of fraud, which are listed below.

Proposed model Scenarios

Table 1 describes the proposed model scenarios that are under consideration.

Table 1: Proposed modeling scenarios

Case number	Case Scenario	Case Description
1	Base model (with fraud)	The first case models the basic simulation of the warranty service operation with the inclusion of fraud originating from the WA. The customer submits a maintenance claim for a product that is in warranty, the service agent then processes this claim and performs the appropriate warranty service activity (repair/replacement) and lastly the warranty administrator reimburses this claim while performing fraud should the opportunity presents itself. Additionally the warranty provider performs an occasional audit to verify the claim. This scenario is considered to examine the titular fraud in isolation.
2	Fraud Mitigating Scenario	This case models the inclusion of mitigating factors to the system. These take the form of business practices and smart ways to detect fraud. We consider the potential negative side effects as well.
3	Multi fraud scenario (with SA)	The final scenario models the basic operation of the warranty service operation with fraud originating from multiple sources, i.e. the service agent and the warranty administrator operate in a dishonest fashion. The customer submits a maintenance claim for a product that is in warranty, the service agent then processes this claim and performs the appropriate warranty service activity (with the possibility of initiating fake claims or overcharging individual claims). Additionally the warranty administrator reimburses this claim while performing fraud should the opportunity presents itself.

Modeling and Assumptions

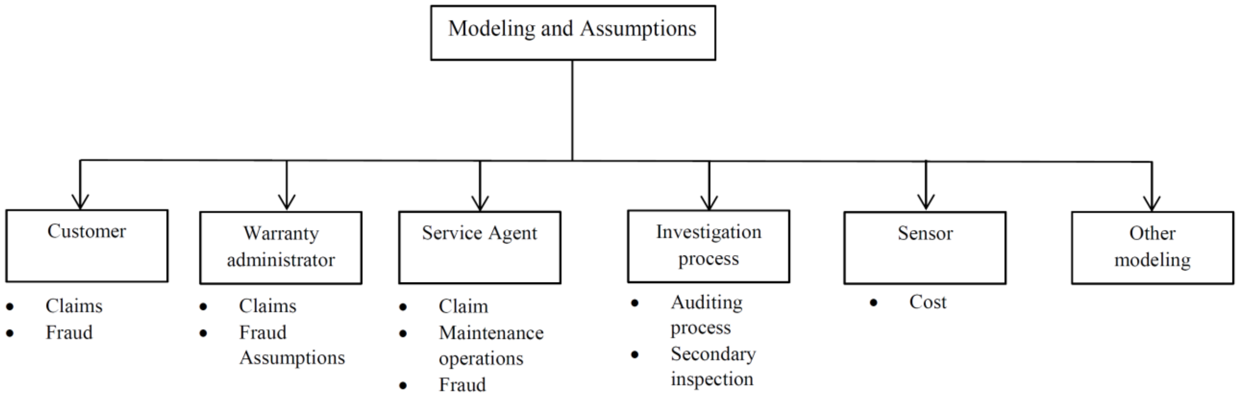

Figure 3: Modeling and Assumptions

In order to accurately recreate the fraud scenario, we model its key aspects, as shown in figure 3. The following section elaborates on the factors that influenced the modeling of each aspect of the fraud scenario. Additionally, we outline assumptions and the reasoning behind excluding certain facets of fraud.

Customer modeling

a. Customer claims

We assume that issues (problems) that result in a maintenance/refund claim being submitted by the customer to service provider fall into one of two broad categories (as described by table 2). 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.

Table 2: Customer maintenance issues

Claim type	Maintenance issues	Cause of issue
Customer	Superficial problems	These encompass issues the customer has with the product that are purely "surface level" and do not affect a products functionality. These problems can be real but are most often subjective. (Example: Scuff marks on a phone casing, "warping" of display screen etc.).
	Functionality problems	These issues 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 be the less expensive option.

b. Customer fraud

The literature notes that there are instances of customer driven fraud [11]. However for this study, we do not consider fraud originating from the customer

Warranty administrator modeling

a. Warranty administrator Claims

WA 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. Unlike with the SA, there is no built-in mechanism to monitor WA activity other than during an audit. In addition, unlike the SA the WA is in a better position to hide its activities from the WP.

b. Warranty administrator fraud

The reasons that a WA might commit fraud are similar to what motivates the SA. WA fraud is therefore based on prevailing fraud theories namely that its occurrence is due to the competing interests of pressure, rationalization and opportunity, or in the case of our model a combination of opportunity and motivation (table 3).

Table 3: Customer maintenance issues

Fraud Drivers	Modeling Fraud
Motivation	For the model, opportunity is interpreted as the allowance between what the actual service charge was verses what the maximum amount that prior data suggests that the amount could be I.e. Opportunity (potential fraud size) = Maximum allowable amount for the Service charge operation based on prior service history (expected amount) – Actual amount charged by the agent charges (reimbursement) Opportunity represents the "means" to commit fraud and not the motive
Opportunity	This factor combines the dueling aspects of pressure and rationalization. The GT model used by Kurvien and Murthy (2016) modeled risk (cost VS benefit) as a means to model rationalization the decision to commit fraud. The results of this study are applied in this case (where the opportunity is the benefit, and getting caught is the cost). Pressure arises from outside forces that cannot be accurately modeled and cannot be entirely quantified. Therefore we consider two scenarios, one where there is no (zero) pressure to commit fraud (no fraud scenario, case 1), and the other where there is pressure (nonzero) to commit fraud (fraud scenario, case 2).

Service agent modeling

a. Service agent claims

Service agent claim data details the amounts that the SA charges in 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.

b. 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 (table 4).

Table 4: Service agent operation categories

Operation category	Operation description
Repair	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 smart screen replacement. A more standard inspection for wear and tear is also considered as part of this operation
Replacement	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, the product being too old such that getting replacement parts proving too difficult etc.

c. 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 5.

Table 5: Factors that influence service agent fraud

Factors	Rationale
Previously escaped	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 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)

Investigation process

a. 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.

b. Secondary inspection assumptions

The secondary inspector is prone to error (both Type I error and Type II error). This leads to 4 different outcomes of the investigation. In addition it is assumed that multiple inspectors are being employed whose experience and competence varies. To represent this variability, multiple inspectors of differing capability are considered. The secondary inspection can be triggered by a number of different factors which are outlined in table 6.

Table 6: Factors that influence secondary inspection

Factors	Rationale
Random Inspection	From time to time, claims may be randomly selected to go through a secondary fraud inspection.
Inspection triggered by warning signs	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 inspection	If a number of SA claims go through 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 un reviewed by the secondary inspectors)

Sensor behavior assumptions

Based on work by Ondemir and Gupta [12], we assume the following relationship (equation 1) between 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 a more likely to be fraudulent and reduce the need to look at a random selection of claims.

$$SC = 1 - e^{(-0.3*n)}$$

(1)
Where,
n – Cost ($), is a non-negative integer
SC- Sensor accuracy

Other model assumptions

Some other model considerations were made

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

Design of experiment

Based on the different factors that have been laid out, the flow of the claim investigation process in regular systems is depicted in figure 4. 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.

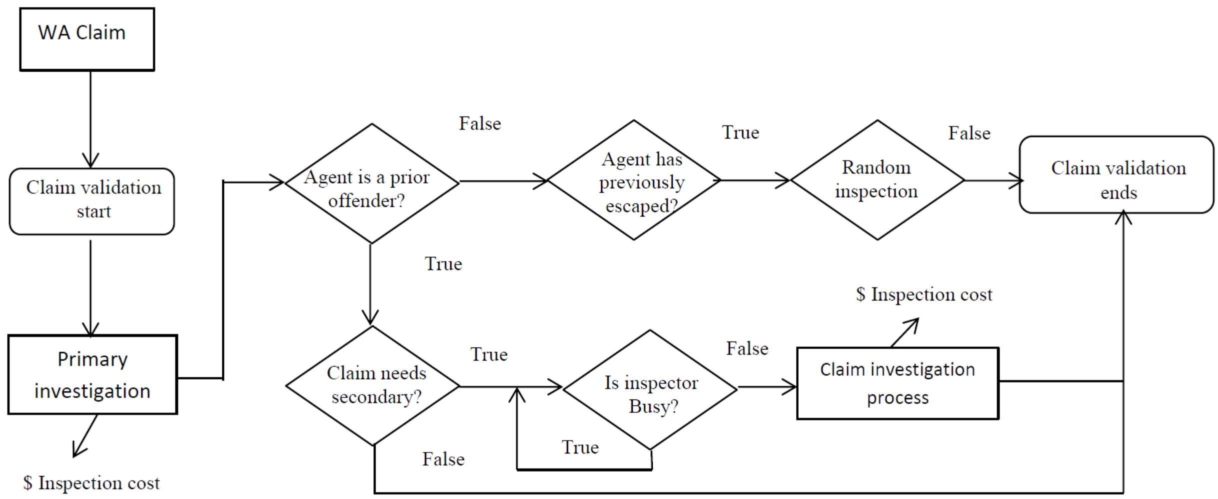

Figure 4: Warranty service investigation process

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 5.

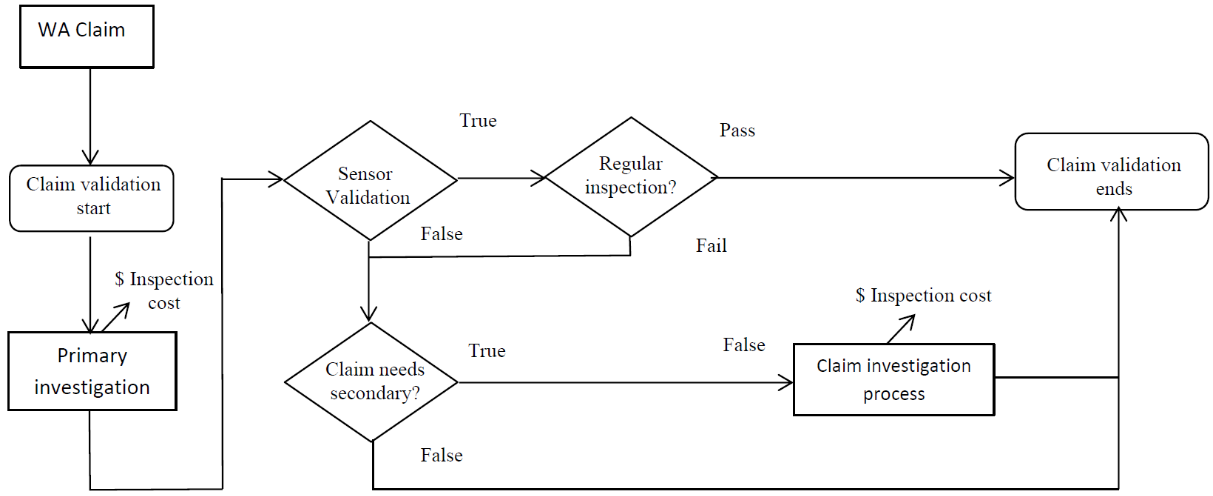

Figure 5: Warranty service investigation process (sensor embedded)

The flow of the claim review process has been established; next the details of the time and cost-dependent processes are defined. 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 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.

IV. 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 7.

Table 7: Remanufactured product details

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 which of the maintenance operations being is carried out (table 8).

Table 8: Maintenance costs

Assumed costs	Dollar amount($)
Standard product inspection cost/product	5
Replacement screen	69
Replacement battery	30
Cost/audit	5
Cost/inspection	15

The costs (from the audit inspection) that were employed in this simulation model are shown in table 8. 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 9 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 9: Process times (distribution)

Assumed times	Distribution function	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 and associated costs

There are two sources of fraud that are assumed in the model, those originating from the WA and those originating from the SA (case 3).

The WA has access to the vendor master data as well prior claim records, and has the ability to manipulate records after the fact, and as such commits fraud in amounts such that the total value of said fraud does not exceed the expected value of the claim by a statistically significant amount at the time of audit.

On the other hand the SA does not have quite the same luxuries as the WA and has a number of factors that affect its decision making. The service agents 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 have been represented in figure 6. 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 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, as shown in equation 2 & 3)

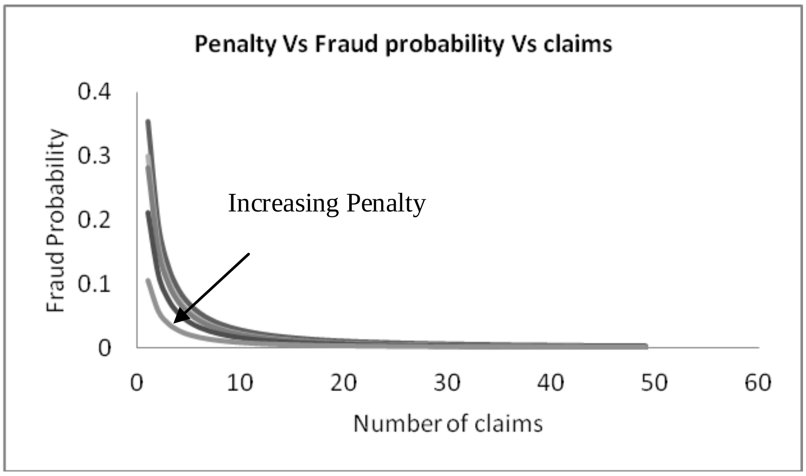

Figure 6: Relationship between fraud probability, penalty value and number of claims

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. The probability of random inspection is expressed in equation 3.

$$P.CF = 1 - e^{(-0.3*C.SA)} \quad (2)$$

$$P.I = 1 - e^{(-0.4*C.UC)} \quad (3)$$

Where,
P.CF – Probability of committing fraud
P.I – Probability of inspection
C.SA – Claims (service agent)
C.UC – Claims (unchecked claims)

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 Service agent decreases dramatically. Similarly if the inspections probabilities are set to be below 0.5, over time the probability of committing frauds 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. The performance measures that were used to calculate this amount is shown below.

V. RESULTS AND DISCUSSION

5.1 Case Analysis

For the base model, over a period of 60 months 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 \$ 305,620 and \$ 126,490 respectively by the WA. Additionally 2581 claims resulted in full replacements

For the first fraud model, the scenario was recreated with the inclusion of WA 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 multi fraud model (WA-SA) each system, RS and SEP system, experiments were carried out, and the data pertaining to the total profit, inspection cost, and fraud costs were tracked. Table 9 contrasts the difference between the base, SEP and multi fraud scenario by describing statistics pertinent to fraud detection and inspections.

Table 9: Fraud detection statistics

Claims statistics	Multi fraud scenario (RS)	Multi fraud scenario with sensors (SEP)	Percentage Improvement (%)
Uncaught false claims	535	375	29.90
Uncaught false claims (only manual)	535	290	45.79
Uncaught false claims (with sensor)	-	80	
Falsely charged	205	170	17.07
Caught fraud(from investigation)	340	320	5.88
Total general audits	4250	3750	11.76
Total claims flagged by sensors	-	545	
Total inspection	2030	1895	6.65
True claims(from investigation)	1395	1335	4.30
Average time in system (hours)	79.5923	72.4505	8.97
Number of claims that fools Sensors	-	95	-
Number of true claims that are flagged by sensors	-	405	-
Approved claims	3705	3255	12.14
Max Queue length(primary)	3	2	33.33
Max Queue length(secondary)	5	3	40

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 $26,885 while this rose to $28,460 in 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	26,885	28,460
Uncaught fraud costs	16,535	13,125
Total costs	62,175	60,335

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

Measure	Mean Difference($)	p- Value
Inspection costs	-1575	<0.0001
Uncaught fraud costs	3410	<0.0001
Total costs	1840	<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 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 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. There also exists a positive correlation between inspection cost and the total cost.

With regards to how the SA fraud affects the likelihood of WA committing fraud, as expected the model shows that there is a negative correlation between the two (I.e. the more SA fraud the lower the likelihood of WA committing fraud). It was noted that there was a 62 % decrease of WA committing fraud for a fraudulent SA claim. While the overall fraud to the WP went up the, the WA fraud went down for battery repair and screen repair by 35% and 28 % respectively.

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 limitations and possible future extensions are listed below.

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

VI. CONCLUSION

The paper examined the issue of warranty administrator fraud and modeled and analyzed three different fraud scenarios. Discrete event simulation was found to be useful in tackling cases where there are multiple fraudulent actors working in collaboration. The SEP system generally yielded positive results. The paper also established some relevant correlations between types of fraud.

REFERENCES

[1]. Hanna, M. D., Newman, R. W., & Johnson, P. (2000). Linking operational improvement through employee involvement. *International Journal of Operations and Production Management*, *20* (2), 148–165.
[2]. Green, B. P., & Choi, J. H. (1997). Assessing the risk of management fraud through neural network technology. *Auditing-A Journal Of Practice & Theory*, *16*(1), 14-28.
[3]. Mu, E., & Carroll, J. (2016). Development of a fraud risk decision model for prioritizing fraud risk cases in manufacturing firms. *International Journal of Production Economics*, 173, 30-42.
[4]. Zhang, H., Hu, Y., & Zhou, Z. (2010). Prevention of resource trading fraud in manufacturing grid: a signalling games approach. *International Journal of Computer Integrated Manufacturing*, *23* (5), 391-401.
[5]. Pandit, A., & Gupta, S. M. (2019b).Impact of warranty fraud on remanufactured products. *Proceedings of International conference on remanufacturing*, Amsterdam, Netherlands.
[6]. Pandit, A. & Gupta, S. M. (2020).Analytical approaches to tackling fraud in a remanufacturing environment, *Proceedings of Decision sciences institute*. Virtual conference. Nov 20-23.
[7]. Kurvinen, M., Töyrylä, I., & Murthy, D. N. P. (2016). *Warranty fraud management: reducing fraud and other excess costs in warranty and service operations*. Hoboken, New Jersey: Wiley.
[8]. Jack, N., & Murthy, D. N. P. (2017). Game theoretic modelling of service agent warranty fraud. *Journal of the Operational Research Society 68*(11), 1399-1409.
[9]. Pandit, A., & Gupta, S. M. (2018). Warranty fraud in remanufacturing. Proceedings of the Global Interdisciplinary Conference: Green Cities, June 27- 30, Nancy, France.
[10]. Pandit, A. & Gupta, S. M. (2019).Warranty Fraud in a Remanufacturing Environment, in *Responsible Manufacturing - Issues Pertaining to Sustainability*, Edited by A. Y. Alqahtani, E. Kongar, K. K. Pochampally and S. M. Gupta, CRC Press, 11, 241-261.
[11]. Pandit, A., & Gupta S. M. (2018). Mitigating customer driven fraud for remanufactured products in reverse supply chain. *Proceedings of 16th International Logistics and Supply Chain Congress*, Denizli, Turkey.
[12]. Ondemir, O., & Gupta, S. M. (2014). Quality management in product recovery using the Internet of Things: An optimization approach. *Computers in Industry*, 65(3), 491-504.
[13]. Pandit, A. & Gupta, S. M., (2020). Predicting Remanufactured Product Fraud using Neural Networks. *Proceedings of the 2020 Annual Meeting of the Northeast Decision Sciences Institute*, Cambridge, Massachusetts, 712-719.

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