

University of Wales Trinity Saint David
School of Engineering



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Development of a Standardised Workflow and Digital Reporting System for Warranty Analysis

Johnpaul Jones (2206145)

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1. Declaration of Authenticity

'This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.'

Signed: Johnpaul Jones Date: 31/05/2026

2. Abstract

Warranty analysis within EnerSys is carried out across multiple laboratory sites. Differences in testing, decision-making and reporting practices can lead to variation in the investigation routes taken. This affects turnaround times along with data quality. This project aimed to develop a more consistent and well-structured approach to warranty analysis through a standardised workflow, decision-making framework, and digital reporting system focused on Energy Systems products.

The project followed an applied engineering approach. Existing warranty processes and claim responsibility data were reviewed to identify areas of variation and inefficiency. A standardised workflow was then developed to guide investigations through intake, visual inspection, electrical assessment, controlled testing, and autopsy. This was supported by decision logic intended to reduce unnecessary testing while retaining engineering judgement for complex cases. A digital reporting system was also implemented using Power Apps, SharePoint Lists, Power Automate, Microsoft Teams, and Power BI to support structured data capture, automated report generation, centralised storage, and basic visualisation.

The validation was conducted with three participants and 30 representative warranty cases. The validation dataset produced an average completion duration of 13.7 days, compared with historical laboratory averages of 31 days in Newport and 16 days in Arras. Reporting consistency received high feedback scores, ranging from 4.6 to 5.0 out of 5, and all participants completed the required safety checks. The results suggest that the strongest benefit of the proposed approach is improved consistency and trainability rather than speed alone.

Although the validation was carried out on a pilot scale and under supervised conditions, the project demonstrated that the proposed workflow and digital system can support a more standardised approach to warranty analysis.

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6. Introduction

6.1 Company & Project Context

The project was undertaken within EnerSys, a global provider of stored energy and power solutions for industrial applications, including communications networks, data centres, transportation and motive power systems (EnerSys, 2026a). As part of its operations, EnerSys manages warranty claims for returned products, which need detailed laboratory analysis to determine failure modes and assess claim validity.

Warranty testing is carried out across multiple laboratory sites, including facilities in the United Kingdom, France and Poland. These laboratories perform a range of activities, including electrical testing, recovery procedures, and physical autopsy analysis on returned units. The results of these investigations are used to support claim decisions and to provide feedback on product performance and design.

Each site has developed its own working practices over time. There are differences in the sequence of operations, specifically in the level of analysis and how results are recorded and reported. This variation can affect process efficiency and make it harder to directly compare results between sites.

Alongside this, an increasing volume of warranty claims and discussions regarding the development of a new centralised EMEA laboratory have highlighted the need for a more standardised approach. Establishing a consistent workflow and standardised reporting system would support improved turnaround times, better data quality, and more effective knowledge sharing across the organisation.

6.2 Problem Statement

Warranty analysis within EnerSys is currently performed across several laboratory sites, each using slightly different testing and reporting approaches. While the core principles of battery testing are consistent, the lack of a standardised workflow means that investigations can vary depending on the location or engineer involved.

This variation creates several issues. Differences in the order of testing, recovery procedures, and autopsy activities can lead to repeated testing or delays in progressing a case. In some situations, engineers rely on local practices or prior experience, reducing decision-making consistency and repeatability across sites.

Another key issue is how data is recorded and stored. Warranty results are often captured in different formats across sites, making them difficult to compare and centrally accessible. This makes it difficult to identify wider patterns, share knowledge across teams, or use data to support product improvement.

With increasing pressure to reduce claim durations and provide consistent customer reporting, these inconsistencies become more significant. Without a unified process and a standardised approach to data capture, it is challenging to ensure efficient and consistent warranty analysis across the organisation.

As a result, there is a clear need for a standardised workflow and reporting system that can be applied consistently across relevant sites.

6.3 Project Aim

The aim of this project is to develop a more consistent, standardised approach to warranty analysis across laboratory sites. This involves developing a standard workflow by introducing a clear decision-making process and implementing a digital reporting system to improve how tests are carried out and recorded.

6.4 Objectives

The objectives of this project are:

- Review the current warranty analysis processes used across laboratory sites and identify primary areas of variation and inefficiency.
- Develop a standardised workflow that defines a consistent sequence of operations for testing, recovery, and autopsy.
- Create a decision-making framework to guide engineers through the analysis process and improve consistency of engineering judgment.
- Design and implement a digital reporting tool that captures results in a structured and consistent format.
- Integrate automated reporting to generate and distribute outputs efficiently.
- Validate the proposed system using sample warranty cases and compare it against the existing approach.

6.5 Scope & Limitations

This project focuses on developing a standardised warranty analysis system for Energy Systems products, including the design of a structured workflow, a decision-making framework, and a supporting digital reporting tool. The work is based on existing laboratory practices at EnerSys and aims to improve consistency, efficiency, and data capture across relevant laboratory sites.

The scope of the project includes the design and pilot implementation of the workflow and reporting system, along with initial validation using selected warranty cases. The digital solution was developed using Power Apps and supporting Microsoft tools to demonstrate how structured data capture and automated reporting can be achieved within the existing organisational environment.

However, the project is limited to a defined set of validation cases and does not represent a full-scale implementation across all sites. Long-term performance, scalability, and integration with wider business systems have not been fully evaluated. In addition, other product groups, particularly motive-power applications, may require separate workflow and reporting adaptations due to differences in testing requirements, failure-analysis methods, and report structure.

7. Literature Review

7.1 Standardisation in Engineering and Laboratory Processes

Standardisation is a key principle within engineering and quality management because it improves consistency, repeatability, and traceability. ISO 9001 identifies process control and documented information as important elements of a quality management system, helping organisations ensure that activities are performed consistently and that outputs remain comparable and auditable (ISO, 2015). Similarly, technical standards such as IEC 60896 and IEEE 1188 define recognised methods for battery assessment, enabling results to be evaluated consistently across users and organisations (IEC, 2004a; IEC, 2004b; IEEE, 2025).

In laboratory and testing environments, standardisation is particularly important because the value of results depends not only on the test performed, but also on the consistency of the method, data capture, and reporting process. Balaji et al. (2026) demonstrated this by developing standardised fuel-cell testing standards to improve inter-laboratory comparability and performance benchmarking across multiple manufacturers and test locations. Although focused on fuel cells, this illustrates the wider engineering principle that standardised procedures are necessary where results must be compared across sites.

However, effective standardisation requires a balance between control and flexibility. Claim investigations typically involve differences in product condition, application history, and failure mode, which means that inflexible processes result in unnecessary work, while overly flexible processes may cause variation and inconsistency. This is particularly relevant to warranty analysis, where comparable cases may otherwise follow different investigation routes depending on local practice or individual experience.

Standardisation also supports knowledge transfer. Klippert et al. (2023) argue that engineering organisations rely on the effective transfer of knowledge between individuals and teams, particularly when expertise is concentrated within experienced personnel. Structured workflows can help convert experience-based knowledge into a repeatable process, reducing dependence on informal mentoring while supporting training, succession planning, and cross-site alignment.

7.2 Battery Testing, Failure Analysis and Warranty Investigation

Battery warranty analysis requires a standardised approach because returned products can fail due to manufacturing defects, application misuse, end-of-life degradation, poor maintenance, or external damage. For stationary lead-acid and valve-regulated lead-acid batteries, recognised standards provide an important technical foundation. IEC 60896-21 defines test methods for valve-regulated stationary lead-acid cells and batteries, while IEC 60896-22 specifies requirements for VRLA batteries used in stationary standby applications (IEC, 2004a; IEC, 2004b). IEEE 1188 provides recommended practice for the maintenance, testing, and replacement of VRLA batteries in stationary applications, while IEEE 450 provides equivalent guidance for vented lead-acid batteries (IEEE, 2025; IEEE, 2020). These standards establish accepted approaches to condition assessment and performance evaluation, but they do not define a complete warranty workflow from receipt through inspection, testing, recovery, autopsy, and reporting.

Lead-acid battery failure is often multi-causal and cannot always be identified from a single measurement. Shi et al. (2013) identify common VRLA degradation mechanisms, including sulfation, water loss, positive grid corrosion, active-material shedding, internal

short circuits, and mechanical damage. These mechanisms can present through different symptoms, meaning diagnosis usually requires multiple forms of evidence. This supports a staged process where non-destructive assessment is carried out before more invasive analysis.

Visual inspection is therefore an important first stage. Physical signs such as leakage, swelling, damaged terminals, corrosion, impact damage, or contamination can provide early evidence of misuse and installation issues. This stage also reduces safety risk by identifying batteries that may not be suitable for charging or electrical testing.

Electrical testing provides the next stage of evidence. Open-circuit voltage, impedance, charge acceptance, and discharge performance can be used to assess whether a battery is deeply discharged, degraded, or capable of delivering usable capacity. Shi et al. (2013) show that non-destructive measurements can support diagnosis of sulfation and water loss, while Demirci and Taskin (2021) show that automated measurement, analysis, and reporting can improve lead-acid battery test consistency against defined procedures.

Where electrical testing is inconclusive, destructive analysis or autopsy may be required. Yan et al. (2004) demonstrate the value of autopsy and material analysis in identifying VRLA failure mechanisms such as positive active-material softening and shedding after high-power cycling. While this level of analysis is not required for every warranty case, it shows that an autopsy can provide important evidence where electrical behaviour alone is insufficient.

However, while standards and technical studies provide guidance on individual tests and failure mechanisms, they do not fully define how these activities should be sequenced within a practical warranty process. This creates a need for an operational workflow that defines the testing order, stopping points, escalation routes, and reporting requirements, while remaining flexible enough to handle different products, applications, and failure modes.

7.3 Decision Trees and Decision Support Methods

Decision support methods are used in engineering and quality management to ensure decisions are made consistently from defined inputs. In this project, the decision tree is not intended to automatically predict battery failure, but to guide engineers through a consistent investigation route based on evidence, test results, and escalation points. This is important because warranty analysis still requires engineering judgement, particularly when failure modes are unclear or multiple factors are present.

Decision trees provide a transparent and repeatable method for structuring decisions. Rastghalam et al. (2026) demonstrate the use of decision tree methods in quality prediction and improvement, showing how process information can become interpretable rules. Although their work relates to production quality rather than warranty investigation, it supports the principle that decision trees can make quality decisions more visible and consistent.

Transparency is important in troubleshooting because users need to understand why a route or outcome has been selected. Qu et al. (2024) argue that interpretable decision-support methods can improve troubleshooting by identifying contributing factors and supporting explainable corrective actions. This is relevant to warranty analysis because investigation decisions must be traceable and justifiable, particularly where the outcome affects claim acceptance or rejection.

However, decision support systems must be applied carefully in complex technical environments. A rigid decision tree may reduce variation but could oversimplify cases where evidence does not fit a predefined route. Reitsma et al. (2019) highlight that decision support is most effective when it supports individual decision-making rather than replacing it entirely. This is consistent with warranty analysis, where a structured process can reduce unnecessary testing and improve repeatability, but engineers must still interpret unusual results and decide whether further investigation is justified.

The decision tree governs routine decisions using defined rules and thresholds, including whether a battery is safe to charge, whether recovery testing is appropriate, and whether an autopsy is required. More complex cases still require engineering judgement, particularly where results are borderline or customer application factors are involved. This improves consistency and traceability without replacing technical expertise.

7.4 Digitalisation, Quality 4.0 and Low-code Reporting Systems

Digitalisation is increasingly important within quality management because it allows organisations to store, analyse, and share information more effectively. Quality 4.0 builds on traditional quality management by combining digital technologies, structured data, automation, and analytics into quality processes. Carvalho et al. (2021) argue that digital technologies can make quality data easier to access and better integrated with operational processes, while Sony and Naik, (2020) suggest that Quality 4.0 can improve decision-making, traceability, and process visibility when aligned with quality objectives.

This is relevant to warranty analysis because the value of an investigation depends on how information is captured and reused. If results are stored only in individual reports or site-specific formats, it becomes difficult to compare cases, identify trends, or share learning between sites. Sader et al. (2022) note that digital quality systems can improve data availability and process monitoring but require appropriate implementation and user involvement. Tanane et al. (2025) similarly highlight that Quality 4.0 adoption requires an end-to-end approach which considers technology, process integration and organisational readiness.

Low-code development is a practical way to implement digital quality systems without full software development. Martinez and Pfister (2023) define low-code as an approach that enables users with limited coding knowledge to develop custom applications tailored to specific needs. Their study found benefits including faster development, reduced complexity, and greater involvement of business users in translating requirements into working applications. This is directly relevant to this project, where the reporting system had to be developed around existing laboratory practices using tools already available within the organisation.

Microsoft Power Apps is described as a low-code platform for developing applications that modernise processes, while Power Automate is used to create automated workflows between applications and services (Microsoft, 2026a; Microsoft, 2026b). Microsoft (2026c) describes Power BI as a business analytics platform that connects, visualises, and shares data across an organisation, which supports its use in this project for converting structured warranty data into dashboard outputs.

However, low-code systems also introduce limitations. Martinez and Pfister (2023) identify issues such as restricted customisation, scalability, vendor lock-in, licensing cost, and security concerns. These limitations show that low-code is not a complete solution. Its value depends on a suitable data structure, consistent user input, and the ability to scale beyond a pilot implementation.

Digital reporting and analytics can also support a more consistent interpretation of technical information. Demirci and Taskin (2021) demonstrate that automated measurement, analysis, and reporting can improve lead-acid battery testing by reducing subjective judgment. Nickell et al. (2023) show how Power BI can model substantial datasets and create interactive visualisations to support decision-making in investigations. Although based on accounting data, the study indicates the role of dashboard tools in converting structured data into usable insight.

Low-code digital reporting can improve structured data capture, report consistency, and future analytical capability. However, its value is not limited to automated report generation. The long-term benefit lies in creating consistent and searchable data for trend analysis, knowledge sharing, and process improvement. Data quality, validation, user adoption, and integration with wider business systems, therefore, remain important limitations.

7.5 Summary of Literature Gap

The literature demonstrates that each main element required for this project is supported individually. Standardisation literature emphasises repeatable processes, controlled variation, traceability, and knowledge transfer. Battery standards and failure analysis research provide guidance on recognised testing methods and degradation mechanisms. The decision support literature supports structured and explainable decision pathways, while Quality 4.0 and low-code literature demonstrate how digitalisation can improve data capture, reporting, and analytics.

However, these areas are generally treated separately. Battery standards define test methods, maintenance requirements, and replacement guidance, but not a complete operational workflow for warranty investigations. Failure analysis studies identify mechanisms such as sulfation, water loss, corrosion, and active-material shedding, but do not address how laboratories should sequence investigations or standardise reporting across sites. Similarly, Quality 4.0 and low-code research support digital transformation but rarely consider battery warranty analysis specifically.

This creates a divide between published technical battery knowledge and warranty investigation. A warranty laboratory needs valid tests, but also a repeatable process for deciding when each test should be used, when testing should stop, when an autopsy is justified, and how findings should be recorded. Without this structure, similar cases may follow different routes depending on site practice or individual experience.

This project addresses that gap by combining a standardised workflow, decision-making framework, and digital reporting system into a single applied warranty analysis process. The contribution is not the development of a new battery test method, but the consolidation of existing technical knowledge into a repeatable process that supports consistency, traceability, knowledge transfer, and future data-driven improvement.

8. Project Timing Plan

8.1 Initial Project Plan

Figure 8.1 shows the planned and actual project timing plan used to manage the main phases of the project.

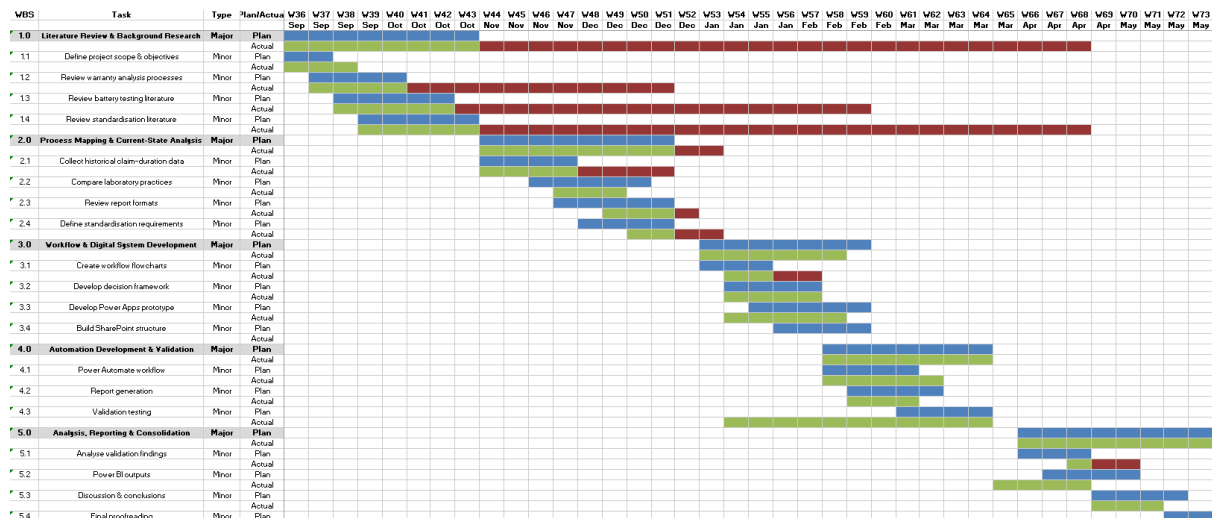


Figure 8.1 - Planned and Actual Project Timeline

The project was initially planned around five main phases: literature review and background research, current-state process analysis, workflow and digital system development, validation and refinement, and final reporting. This structure was created to ensure that a sufficient understanding of existing warranty analysis processes was established before solution development began. The planned sequence reflected the dependencies between activities: workflow development required completion of process analysis, and validation required completion of the workflow and the digital reporting system.

8.2 Iterative Development and Project Progression

Although the overall project followed the planned sequence, several activities overlapped more than originally anticipated. The literature review continued throughout the development phase as additional information was required to support workflow design, decision-logic development, and the evaluation of the final solution. Similarly, validation was iterative throughout the project rather than only at the end. Functional testing and user feedback were used throughout implementation to improve the workflow, reporting structure, and application interface.

The development of the digital system also followed an iterative approach. Initial work focused on basic workflow design and data capture before expanding to include Power Apps functionality, automated report generation, and dashboard visualisation. This approach reduced development risk and allowed individual components to be tested before additional functionality was introduced.

8.3 Scope Refinement

During the process analysis phase, the project scope was reviewed and refined. The initial intention was to consider multiple business lines; however, it became apparent that motive power products required significantly different testing approaches, failure analysis

methods, and reporting requirements. Including these within a single project would have increased complexity and reduced the depth of development achievable within the available timeframe.

The scope was therefore narrowed to Energy Systems products, allowing greater focus on workflow development, validation, and implementation. This decision ensured that a complete and validated solution could be developed while identifying motive applications as a potential area for future work.

8.4 Reflection on Project Delivery

Despite several activities taking longer than originally planned, all major project objectives were completed within the overall project duration. The iterative development process proved beneficial, enabling feedback from testing and user interactions to inform subsequent design decisions. As a result, the final decision-making framework and digital reporting system became more closely aligned with operational requirements.

The project progressed broadly in line with the planned timeline while retaining sufficient flexibility to accommodate scope refinement and user-driven improvements.

9. Methodology

9.1 Research Approach

This project followed an applied and iterative engineering approach rather than a traditional experimental method. The aim was to improve warranty analysis by developing a standardised workflow, decision-making framework, and digital reporting system based on existing EnerSys laboratory practices.

The work began with a review of warranty analysis processes across multiple sites, including testing sequences, reporting formats, and decision-making practices. This highlighted differences between locations and helped define requirements for a more consistent process.

The system began with structured data capture through SharePoint Lists before expanding to include a Power Apps interface, Power Automate report generation, conditional workflow logic, and report update functionality.

The validation was carried out through functional testing during development and further assessment using representative warranty cases. Feedback from engineers was used to fine-tune the workflow, interface, and reporting structure. This allowed the proposed system to be assessed as both a technical solution and a useful tool for warranty analysis.

9.2 Current-State Analysis of Claim Responsibility and Duration

To support the development of this project, improvements were made to the way claim data was collected and analysed. Existing systems did not provide a precise breakdown of responsibility by process stage, making it difficult to understand where time was being spent. As part of this work, internal EnerSys claim-duration data was collated and structured to allow comparison between sites and across key responsibility stages. This enabled a more detailed assessment of current process performance and variation.

A breakdown of average claim open days by site and responsibility is shown in Table 9.1.

Table 9.1 - Average Claim Open Days by Site and Responsibility (EnerSys, 2026b)

Responsibility / Stage	Newport	FRSM	Arras	Bielsko-Biala
<i>Closure (Accepted)</i>	54	82	76	46
<i>Closure (Rejected)</i>	99	37	64	32
<i>Claim Closure</i>	—	7	13	21
<i>Laboratory</i>	31	—	16	23
<i>Local Quality</i>	29	4	3	1
<i>Customer Service</i>	4	5	16	13

The data shows significant variation in claim duration across sites. The largest values are observed in the closure stages, with closure (accepted) ranging from 46 days at Bielsko-

Biała to 82 days at FRSM, and closure (rejected) ranging from 32 days at Bielsko-Biała to 99 days at Newport.

- Newport shows the highest closure (rejected) duration at 99 days.
- FRSM shows the highest closure (accepted) duration at 82 days.
- Bielsko-Biała consistently shows the lowest durations across most categories.

However, these closure stages require operational knowledge for accurate interpretation. They do not necessarily represent the point at which the customer considers the claim resolved. In many cases, closure reflects internal administrative completion, including crediting, replacement handling, and system updates. As a result, these values include downstream activities that are completed after the customer-facing resolution of the claim.

To better understand technical process performance, it is necessary to consider the laboratory and quality-related stages separately.

Table 9.2 - Summary of Responsibility Stage Performance Across Sites (EnerSys, 2026b)

Responsibility / Stage	Mean (Days)	Min (Days)	Max (Days)	Range (Days)
<i>Closure (Accepted)</i>	64.5	46	82	36
<i>Closure (Rejected)</i>	58.0	32	99	67
<i>Claim Closure</i>	13.7	7	21	14
<i>Laboratory</i>	23.3	16	31	15
<i>Local Quality</i>	9.3	1	29	28
<i>Customer Service</i>	9.5	4	16	12

When comparing responsibility stages across sites, the laboratory stage shows a more consistent range, typically 16-31 days. This indicates that although variation exists, technical investigation is relatively controlled compared to other stages.

- Laboratory duration varies between 16 and 31 days across sites.
- This represents a significantly smaller range than closure stages (up to 67 days variation)
- Technical investigation is not the primary driver of overall process variation.

In contrast, local quality and closure stages show much larger variation. Local quality ranges from 1 day at Bielsko-Biała to 29 days at Newport, indicating differences in how responsibilities are handled and progressed across sites.

- Local Quality varies by up to 28 days between sites.
- Closure stages vary by up to 67 days between sites.

- Customer Service, while lower in duration, still shows variation between 4 and 16 days.

These differences indicate that responsibility ownership, workflow structure, and internal processes are not aligned across sites.

From a process perspective, two key observations can be made. Firstly, a significant proportion of recorded claim duration is associated with closure and administrative stages rather than technical investigation. Secondly, even within the laboratory and quality stages, variation comes from differences in workflow, decision-making, and testing practices.

This aligned with observations from current laboratory processes, where:

- Testing sequences are not standardised across sites.
- Recovery procedures may be repeated unnecessarily.
- Decision-making is influenced by individual experience rather than defined rules.
- Reporting formats differ significantly, limiting comparability.

For example, recovery of severely discharged batteries can be carried out multiple times, despite limited technical benefit. While this may demonstrate charge acceptance, it does not reflect usable performance and can lead to repeat failures if the unit is returned to service. This results in increased testing time without improving the quality of the outcome.

The current-state analysis indicated that claim duration was influenced not only by technical investigation time but also by differences in responsibility ownership, workflow structure, reporting, and decision-making practices. This supported the need for a standardised warranty analysis process with defined stages, controlled testing routes, and consistent data capture.

9.3 Standardised Workflow Development

The standardised workflow was created to address the variation identified in the current process. The main aim was to reduce unnecessary testing, improve consistency between sites, and ensure that safety-critical steps were always followed. Rather than completely redesigning how analysis is carried out, the focus was on structuring what already exists into a clear and repeatable sequence.

A key part of the design was defining a clear “topline” path through the process, representing the fastest route to a decision where sufficient information is available early in the investigation. In the existing process, engineers often followed slightly different approaches depending on their experience or preferences, so similar cases could take very different paths. By introducing a defined sequence with decision points, the workflow allows simple cases to move quickly, while still supporting more detailed investigation where required.

9.3.1 Intake and Visual Inspection

The intake and visual inspection stage is shown in Figure 9.1.

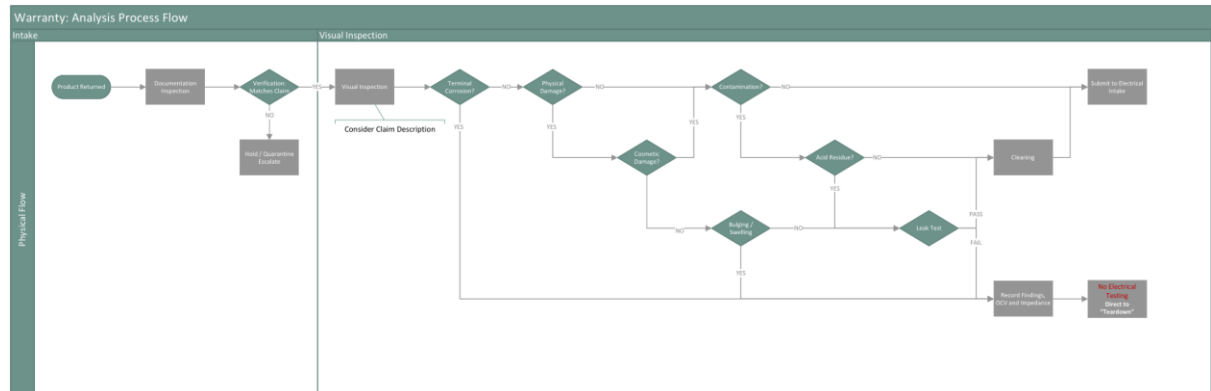


Figure 9.1 - Intake and Visual Inspection Flow

The intake and visual inspection stage was expanded compared to the previous process, which was often brief and inconsistent. In practice, this stage is important from both safety-related and diagnostic perspectives, so it was necessary to define it more clearly.

The updated workflow includes specific checks for physical damage, terminal corrosion, contamination, bulging, and leakage. These checks are used to identify whether a unit is safe to proceed with electrical testing. If a battery shows signs of leakage or structural damage, it is routed directly to autopsy rather than continuing through electrical testing.

This reduces the risk of damaged units being placed on charge, where overheating or thermal events may occur. Previously, this decision was often based on individual judgment, whereas the updated workflow makes this a defined step.

9.3.2 Electrical Intake

The electrical intake stage is shown in Figure 9.2.

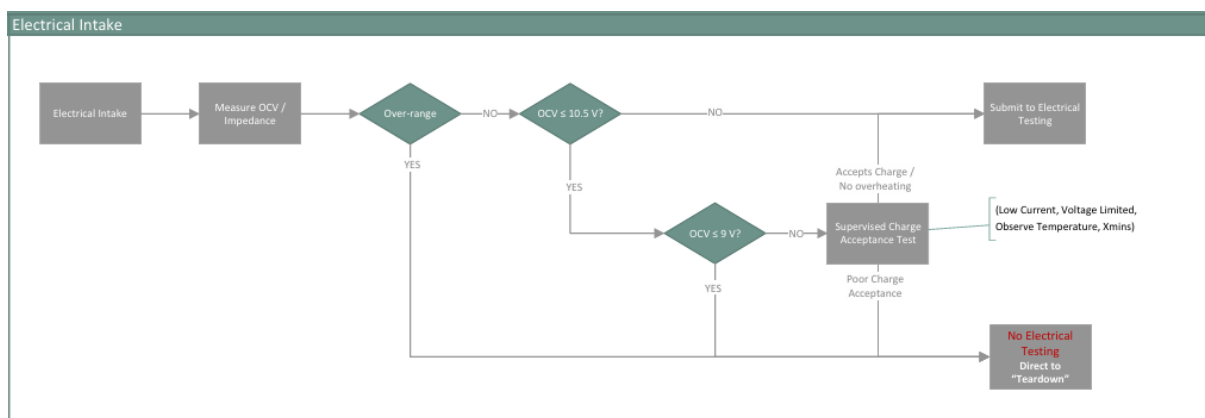


Figure 9.2 - Electrical Intake Flow

Once a unit has passed visual inspection, it moves into electrical intake, where basic measurements, such as open-circuit voltage and impedance, are used to assess product condition.

In the previous process, this stage existed but was not always used consistently to guide decisions. The updated workflow introduces clearer thresholds and routes based on

these values. For example, low-voltage conditions are handled through a controlled charge acceptance process rather than applying a full charge immediately.

Additional attention was given to severely discharged batteries. The lower voltage threshold indicates that the unit may have experienced deep discharge or misuse. While recovery may still be attempted in some cases, it is now done under standardised conditions, with limits on current and temperature monitoring.

This approach reduces the likelihood of repeated or uncontrolled recovery attempts, which were previously observed and did not always provide useful results.

9.3.3 Electrical Testing

The electrical testing flow is shown in Figure 9.3.

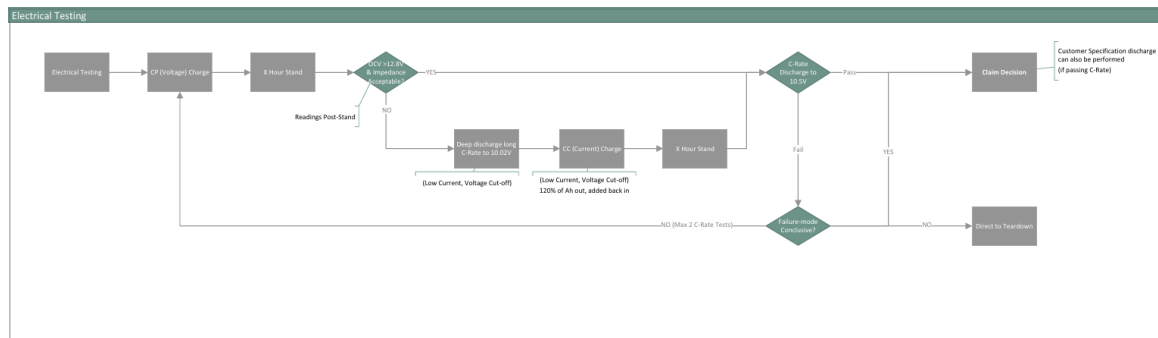


Figure 9.3 - Electrical Testing Flow

The electrical testing stage was standardised to ensure a consistent approach to performance evaluation while limiting unnecessary repetition. In the existing process, the order and number of tests can differ substantially, and in some cases, batteries are cycled multiple times without reaching a clear conclusion.

The updated workflow defines a sequence of testing steps, including controlled charging, stabilisation, and discharge testing. Progression through these steps depends on whether results are considered acceptable or conclusive, rather than continuing testing by default.

Limits were also introduced on the number of test cycles that can be performed. This helps avoid situations where resources are spent repeating similar tests without improving understanding of the failure mode.

A specific issue addressed here is the recovery of batteries at very low voltages. While it is possible to bring these units back to a measurable state, the resulting performance is often not representative of usable service life. Returning these units to the customer can lead to repeat failures, so the workflow reduces reliance on this type of recovery as a primary recovery approach.

9.3.4 Autopsy

The autopsy flow is shown in Figures 9.4 and 9.5.

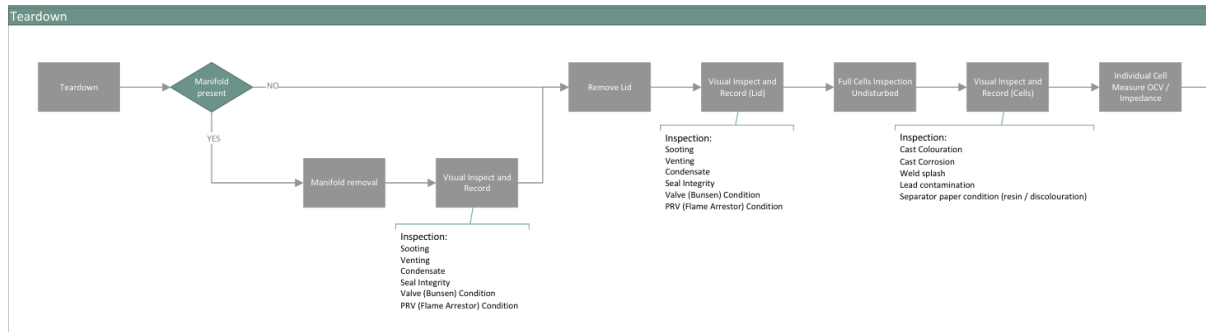


Figure 9.4 - Autopsy Flow (A)

Autopsy is used where electrical testing does not provide a clear conclusion, or where earlier stages indicate that physical damage or failure is likely. In the existing process, the depth of autopsy varied between sites, with some cases being over-analysed and others lacking sufficient detail.

The updated workflow demonstrates a more standardised approach to autopsy, including defined inspection steps and limits on the number of cells removed. The number of cells selected for detailed inspection is restricted unless a clear issue is identified, as shown in Figure 9.5.

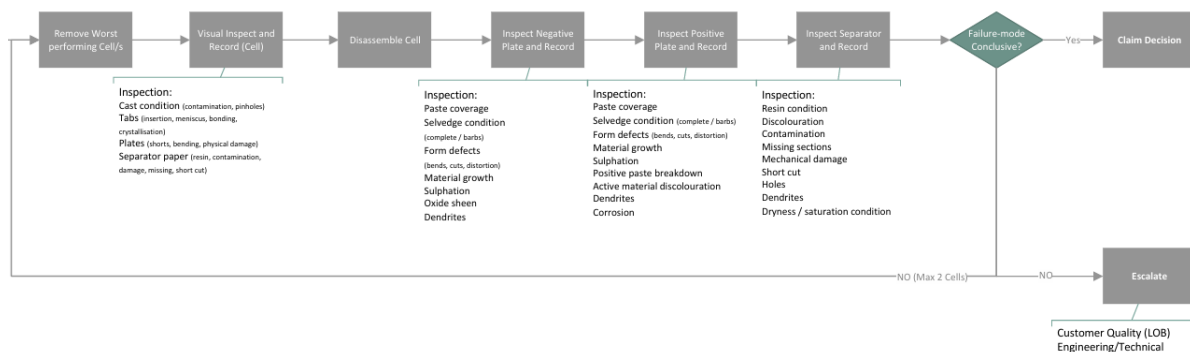


Figure 9.5 - Autopsy Flow (B)

This ensures the autopsy focuses on the root cause rather than becoming an open-ended investigation. It also improves consistency in how results are recorded, which supports better comparison between cases.

9.3.5 Decision Logic and Overall Workflow Design

The final workflow was designed as a structured but flexible decision-making framework. The main sequence of stages is fixed to ensure that critical steps are followed, particularly those relating to safety, initial screening, controlled charging, testing limits, and autopsy routing. However, the workflow also retains flexibility where technical judgement is required, such as interpreting borderline electrical results or considering application-specific requirements.

Decision points were built into the workflow at visual inspection, electrical intake, electrical testing, and autopsy routing. These points control whether a unit is safe to test, whether charge acceptance is required, whether further testing is justified, or whether a

conclusion can be reached. This allows routine decisions to be standardised while still allowing engineers to apply judgement in more complex cases.

The purpose of the decision logic was not necessarily to change the technical outcome of an investigation, but to control how that outcome is reached. By structuring the route through the process, the workflow reduces unnecessary variation, limits repeated testing, and ensures cases follow a logical, repeatable path.

9.4 Digital System Development

The digital system was developed to support the standardised workflow by providing structured data capture, report management, automated document generation, and centralised storage. The system was built using Power Apps, SharePoint Lists, Power Automate, Microsoft Teams, and Power BI to remain compatible with the existing organisational software environment.

9.4.1 Power Apps Interface

The Power Apps interface was developed to provide a standardised way to enter, review, and update warranty analysis reports. It was designed to standardise report entry, reduce manual report-writing effort, and remain compatible with existing operational practices across multiple laboratory sites.

The application is structured around main interface areas, including a landing page, a report gallery, a report viewing page, a report editing page, and a completion screen. The report gallery page acts as the main navigation point for users to access report management functions and supporting data pages. The interface was designed to remain simple and familiar to users already working within Microsoft Teams and associated Microsoft applications.

The main report management area uses a split gallery layout. Existing claims are displayed on the left-hand side of the interface, while associated evidence images for the selected claim are displayed on the right-hand side. The report gallery interface is shown in Figure 9.6.

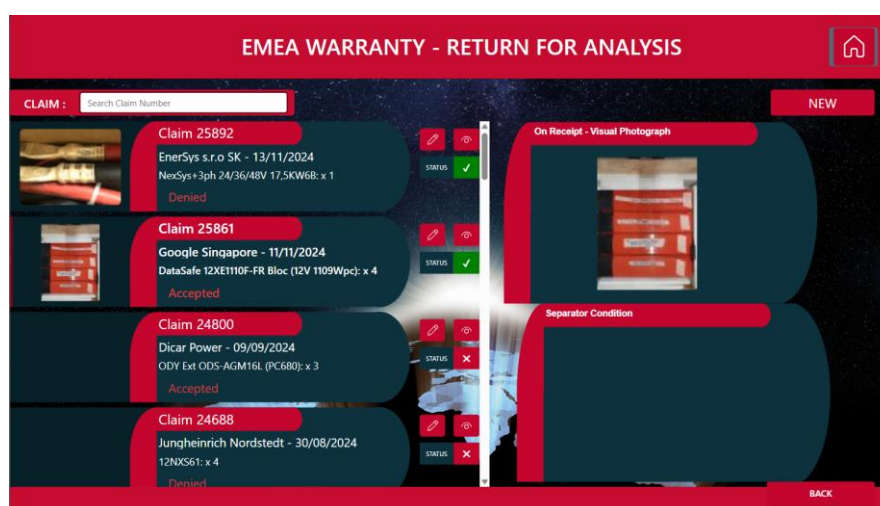


Figure 9.6 - Report Gallery Interface

Each claim entry in the gallery contains summary information, including the claim number, date, quantity, customer, and claim status. Additional controls allow users to either view or edit a selected report directly from the gallery. Search and filtering

functionality is also included, allowing claims to be located using the customer's name or claim number.

The report viewing page allows the user to review all information associated with a specific claim, including structured report fields, observations, and supporting evidence images. The report viewing interface is shown in Figure 9.7.

EMEA WARRANTY - VIEW REPORT

REPORT VIEW

Claim Number
25892

Claim Registration Date
Wed, Nov 13, 2024

Strategic Customer
No

Customer Name
EnerSys s.r.o SK

Business Line
Motive Power

Customer Problem Description
Charger does not recharge the battery to 100% capacity. At 70% charger begins to lower charging voltage, at 80% charger shuts down. At 80% charging capacity the charger behaves as if the battery was fully charged and keeps shutting down.

EVIDENCE

On Receipt - Visual Photograph

Separator Condition

BACK

Figure 9.7 - Report Viewing Interface

The editing page uses the same overall structure as the viewing page but allows users to modify and update information during the investigation process. The report editing interface is shown in Figure 9.8.

EMEA WARRANTY - EDIT REPORT

REPORT EDIT

Claim Number
25892

Claim Registration Date
Wed, Nov 13, 2024

Strategic Customer
No

Customer Name
EnerSys s.r.o SK

Business Line
Motive Power

Customer Problem Description
Charger does not recharge the battery to 100% capacity. At 70% charger begins to lower charging voltage, at 80% charger shuts down. At 80% charging capacity the charger behaves as if the battery was fully charged and keeps shutting down.

EVIDENCE

On Receipt - Visual Photograph

Separator Condition

Tap or click to add a picture

Tap or click to add a picture

SUBMIT BACK

Figure 9.8 - Report Editing Interface

The application was designed to support live working practices, allowing reports to be progressively updated rather than requiring completion in a single session. Users can therefore save and revisit reports during ongoing investigations.

Conditional logic is used throughout the interface to control field visibility and data entry flow. Certain sections are only available when specific investigation stages apply. For example, electrical testing or thermal analysis sections are only enabled when relevant to the selected workflow path. Additional image upload sections can also be enabled where required.

The application follows a structured progression aligned with the standardised workflow. While the workflow itself exists separately from the interface, the page structure and field layout were designed to broadly follow the same sequence of operations.

A temporary completion page is displayed when reports are submitted for finalisation, providing a short delay while report data is transferred into the automation workflow and associated files are generated.

Several interface revisions were made during development in response to user feedback. Earlier gallery layouts used a tiled layout, but users found it difficult to navigate when reviewing large numbers of claims. The layout was therefore changed to a vertical gallery containing key claim information alongside supporting images. Navigation controls were also revised, with several icon-based controls replaced by labelled buttons to improve usability.

Power Apps was selected as the primary interface platform due to its integration with existing Microsoft systems already in operational use within the organisation. This allowed the application to operate directly within Microsoft Teams and simplified deployment across sites.

The interface is primarily intended for desktop and laptop-based use. Although the application can run on mobile devices and tablets, the current layout is not optimised for mobile use. Practical laboratory conditions and existing engineer familiarity with desktop systems also influenced this design approach.

Several limitations remain within the interface. Complex table-based data entry, such as large structured electrical datasets, is not fully supported within the current implementation. Image upload functionality is included, but the quantity and type of visual evidence included in each report remain dependent on reporting requirements and user preference.

9.4.2 Data Structure and SharePoint Lists

The data structure was implemented using a SharePoint List as the backend storage solution, while data entry and interaction were handled through the Power Apps interface. This allowed the application to control how data was entered and displayed, while the list acted as a structured repository. The Power Apps data entry interface is shown in Figure 9.9.

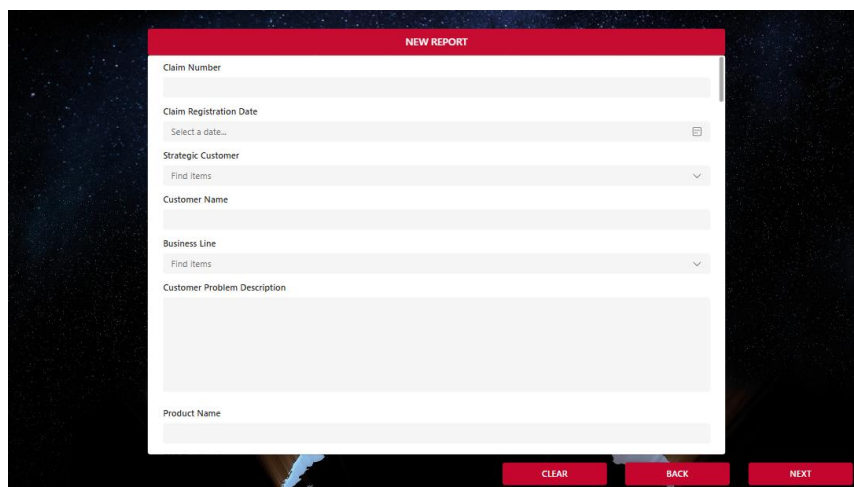
The image shows a screenshot of a Power Apps interface titled "NEW REPORT". The form is white with a red header bar. It contains several input fields: "Claim Number" (text), "Claim Registration Date" (date picker), "Strategic Customer" (dropdown menu), "Customer Name" (text), "Business Line" (dropdown menu), "Customer Problem Description" (text area), and "Product Name" (text). At the bottom of the form, there are three red buttons labeled "CLEAR", "BACK", and "NEXT". The background of the app is a dark, starry space image.

Figure 9.9 - Power Apps Data Entry Interface

Within the application, users complete warranty reports through a structured form, with the underlying data stored in a single list containing many fields. These fields capture all relevant information for a claim, including claim details, product information, inspection results, and final outcomes.

Although the data is stored in SharePoint, users interact only with the Power Apps interface. This allows field visibility, input type, and workflow progression to be controlled within the application. The corresponding SharePoint Lists data repository is shown in Figure 9.10.

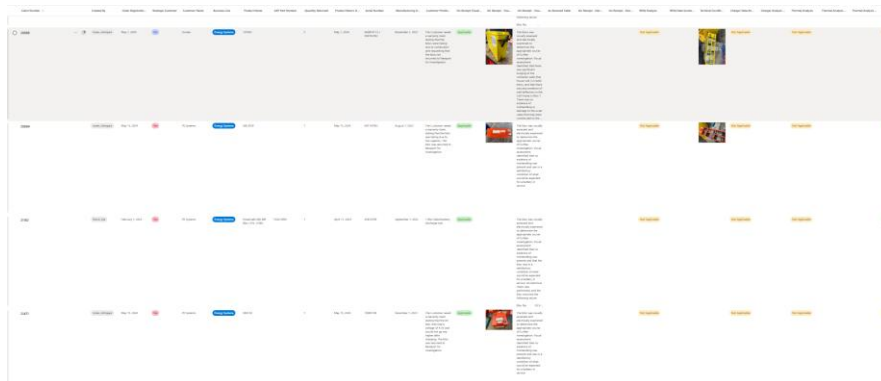
The image shows a screenshot of a SharePoint list interface. It displays a table with multiple rows of data. Each row contains various fields, including text, numbers, and images. The interface has a standard SharePoint look with a header bar and a list of items. The data appears to be organized into columns, with some columns containing images and others containing text or numerical values.

Figure 9.10 - SharePoint Lists Data Repository

The structure incorporates both standardised fields and descriptive inputs. Structured fields such as claim number, business line, liability, and claim outcome are defined using dropdown selections and controlled inputs to ensure report standardisation. At the same time, free-text fields are used to record observations, summaries, and conclusions, allowing flexibility when a detailed explanation is required.

Image capture is also supported within the application, with fields provided for uploading photographs at different stages of the analysis. These include images related to terminal condition, thermal observations, and autopsy defects, which are stored alongside the structured data.

A key feature of the system is the use of conditional logic within the application interface. Certain fields and sections are only made available when relevant, based on earlier inputs. For example, sections related to autopsy or electrical analysis are enabled only when applicable to the case. This helps guide the engineer through the process and prevents unnecessary or incorrect data entry. An example of conditional field logic is shown in Figure 9.11.

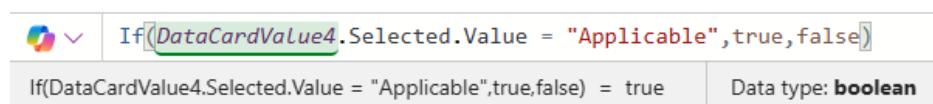


Figure 9.11 - Example of Conditional Field Logic

The system does not currently store detailed raw test data, such as full electrical datasets or discharge curves, within the list itself. Instead, this information is summarised in text fields or attached externally where required. This limits deeper data analysis but provides enough flexibility and standardisation, within current platform constraints.

The data structure supports a controlled and consistent approach to capturing warranty analysis information. While not fully integrated or optimised for advanced data

Once the Word document is generated, it is automatically converted to PDF format. Both versions are then saved to a designated location within Microsoft Teams, providing a centralised, accessible storage location for all reports.

The workflow also includes logic to manage report updates. If a report is edited after its submission, the system checks whether an existing version exists. If so, the previous files are deleted and replaced with the updated versions. This ensures the latest report is available and removes the need for administrative version control. The file replacement logic is shown in Figure 9.14.

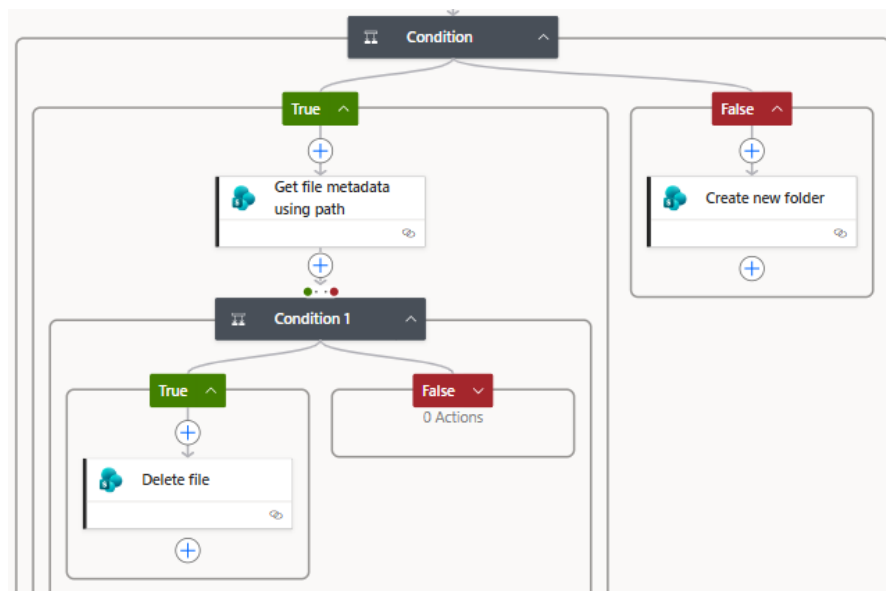


Figure 9.14 - Conditional Logic for File Replacement

This acts as a form of error-proofing. If information is entered incorrectly or later requires amendment, the user can revise the data within the application and regenerate the report, with the stored output updated automatically.

The automation itself is intentionally kept relatively simple, focusing on reliability rather than complexity. It ensures that data captured in the application is directly translated into a consistent output format, eliminating the need for administrative formatting and reducing variation across reports.

As with the data structure, the current implementation has limitations. The inclusion of images and more structured data formats, such as tables, is not fully supported within the generated outputs. This restricts the level of detail that can be included in reports and highlights an area for future improvement.

The automation workflow provides a consistent and repeatable method for generating and managing warranty reports. It improves alignment between captured data and final outputs while reducing administrative work associated with formatting and version control.

10. Results

10.1 Validation Findings

The validation of the proposed warranty analysis system was conducted through a pilot-scale assessment involving three participants with varying levels of experience in warranty analysis. The validation exercise utilised thirty representative warranty cases, primarily focused on Energy Systems products, with selected additional cases used to assess whether the workflow could accommodate wider claim variation.

In addition to workflow validation, an indicative labour assessment was developed to estimate the effort associated with different warranty investigations. Labour effort was estimated using investigation duration, participant labour rate, and report preparation time. Participant labour rates were assigned according to experience level, with experienced, intermediate, and limited-experience users assigned representative hourly rates based on internal engineering resource costs. Reporting effort was recorded separately and rounded to the nearest 15-minute interval to reflect practical report preparation activities. The resulting values were used to provide an indicative comparison of labour effort between claim types and complexity levels rather than a business-case cost model.

10.1.1 Participant Profile

Table 10.1 summarises the participants involved in the validation exercise.

Table 10.1 - Participant Profile

Participant	Experience Level	Site	Process Exposure
<i>P1</i>	Experienced	Newport	Yes
<i>P2</i>	Intermediate	Arras	Partial
<i>P3</i>	Limited	Newport	No

The inclusion of engineers of different levels of experience was intended to assess whether the workflow reduced dependence on individual knowledge and promoted a more consistent approach to investigation.

10.1.2 Case Selection

A total of thirty representative warranty cases were selected, primarily from Energy Systems, with selected Transportation and Aerospace & Defence cases included to test workflow flexibility. Cases included a mixture of accepted, rejected and partially accepted claims, as well as a range of battery failure modes and investigation requirements.

Cases were categorised according to complexity using the definitions shown in Table 10.2.

Table 10.2 - Complexity Definitions

Complexity	Definition
<i>Low</i>	Failure mode and responsibility can be determined with minimal investigation and limited ambiguity.
<i>Moderate</i>	Failure mode and/or responsibility require structured investigation, testing, or evidence review before a conclusion can be reached.
<i>High</i>	Failure mode and/or responsibility require extensive investigation due to multiple potential causes, ambiguity, application influences, or the need for detailed technical analysis.

10.1.3 Workflow Completion Performance

Workflow completion time was one of the primary performance measures. The recorded completion times indicated a clear relationship between case complexity and investigation duration. Table 10.3 summarises the workflow completion times.

Table 10.3 - Workflow Completion Time Summary

Complexity Level	Number of Cases	Average Completion Time (Days)
<i>Low</i>	8	9.4
<i>Moderate</i>	14	14.8
<i>High</i>	8	16.3

Low-complexity cases consistently produced the shortest completion durations. For example, cases C25, C13 and C14 were completed in 5, 7 and 8 days, respectively. In comparison, high-complexity investigations such as C1, C2 and C24 required between 17 and 20 days to reach a conclusion. The longest investigation was case C27, which lasted 32 days and resulted in a partial acceptance.

The average completion time increased from 9.4 days for low-complexity cases to 14.8 days for moderate-complexity investigations and 16.3 days for high-complexity investigations. Although investigation duration increased with complexity, many cases remained grouped within a relatively narrow range for each category, indicating that the workflow provided a repeatable structure for progressing investigations.

10.1.4 Workflow Consistency

Workflow consistency was evaluated by monitoring adherence to routes, unnecessary testing, and completion of safety-related activities, as summarised in Table 10.4.

Table 10.4 - Workflow Consistency Evaluation

Participant	Correct Route Followed	Unnecessary Testing Performed	Safety Checks Completed
<i>P1</i>	Yes	Yes	Yes
<i>P2</i>	Yes	No	Yes
<i>P3</i>	Partial	Yes	Yes

All participants completed the required safety checks during validation. Minor workflow deviations were observed when participants elected to perform additional testing before proceeding along the intended route. Despite this, all participants successfully completed the investigation process and reached valid outcomes.

10.1.5 Indicative Labour Assessment

Indicative labour effort was estimated to provide a comparative measure of investigation resource requirements across the validation dataset. Labour cost calculations were based on investigation duration, active labour assumptions, participant labour rate, and report preparation time. Representative labour rates of £20.00/h, £18.50/h, and £15.50/h were assigned to experienced, intermediate, and limited-experience participants, respectively. Report preparation effort was recorded separately and rounded to the nearest 15-minute interval to reflect practical reporting activities. The resulting values are intended as

indicative measures of investigation effort and workflow consistency rather than actual operating expenses.

Table 10.5 - Indicative Average Labour Effort by Complexity

Complexity Level	Number of Cases	Average Total Labour (Hours)	Indicative Average Labour Cost (£)
<i>Low</i>	8	15.0	274
<i>Moderate</i>	14	23.2	405
<i>High</i>	8	25.7	500

The estimated labour effort generally increased with investigation complexity, representing the additional testing, interpretation and reporting requirements associated with more challenging claims. Low-complexity cases averaged approximately 15.0 labour hours and £274, moderate-complexity cases averaged 23.2 labour hours and £405, and high-complexity cases averaged 25.7 labour hours and £500.

Although the average labour cost increased with complexity, there was overlap between categories. This was expected because total labour cost was influenced not only by complexity, but also by claim duration, reporting time, participant labour rate and the specific investigation route followed. The highest individual labour estimate was case C27, which required approximately 50.0 labour hours and produced an indicative labour cost of £1000 due to its extended duration and partial acceptance outcome.

The labour assessment suggests that investigation effort was broadly linked to case complexity, while also demonstrating that individual claim characteristics can create outliers within each category.

10.1.6 User Feedback

Following completion of the validation exercise, participants were asked to evaluate the workflow and reporting system.

Table 10.6 - User Feedback Summary

Evaluation Criteria	P1	P2	P3
<i>Workflow Clarity</i>	4.9	4.9	4.6
<i>Ease of Use</i>	4.3	4.2	4.0
<i>Confidence in Decision-Making</i>	4.8	4.6	3.8
<i>Reporting Consistency</i>	4.6	4.6	5.0
<i>Overall Usability</i>	4.2	4.0	4.4

User feedback was collected following completion of the validation exercise using a simple scoring matrix and supporting discussion. Participants rated the workflow and reporting system on a 5-point scale for workflow clarity, ease of use, confidence in decision-making, reporting consistency, and overall usability.

Workflow clarity received consistently high ratings, ranging from 4.6 to 4.9 out of 5. Reporting consistency also scored highly, ranging from 4.6 to 5.0 out of 5, indicating that participants found the reporting format clear and repeatable. Confidence in decision-

making showed slightly greater variation, with the lowest score recorded by the least experienced participant.

As the validation group consisted of only three participants, these scores should be treated as qualitative feedback rather than statistically representative data. However, the responses indicate that the workflow and reporting system were generally usable and accepted by participants. Supporting feedback also identified areas for further refinement, including improved support for structured electrical datasets, greater reporting flexibility, and further interface improvements.

10.2 Implications of the Results

10.2.1 Standardisation of Warranty Analysis

The main objective of this project was the development of a standardised warranty analysis workflow capable of reducing variation between investigations while maintaining sufficient flexibility to support different failure modes and claim scenarios.

The validation dataset produced an average completion duration of 13.7 days and a median duration of 13.5 days. The close agreement between these values suggests that many investigations remained clustered around the distribution's centre and were not heavily influenced by extreme values. Completion durations ranged between 5 and 32 days, producing a total range of 27 days. While this range initially appears significant, inspection of the dataset shows that most cases remained clustered within a considerably narrower operating window, with the largest outlier associated with a high-complexity end-of-life investigation.

When grouped by complexity, low-complexity cases averaged 9.4 days, moderate-complexity cases averaged 14.8 days, and high-complexity cases averaged 16.3 days. This progression suggests that investigation effort increased with technical complexity as expected, while remaining relatively controlled within each category.

Comparison with historical laboratory data indicates that the proposed workflow may reduce investigation duration when compared with existing site-specific approaches. Newport historically averaged approximately 31 days within the laboratory stage, while Arras averaged approximately 16 days. During validation, Newport-based investigations averaged 14.3 days, while Arras-based investigations averaged 12.9 days. This comparison is summarised in Table 10.7.

Table 10.7 - Historical and Validation Duration Comparison

Site	Historical Average (Days)	Validation Average (Days)	Difference
Newport	31.0	14.3	-54%
Arras	16.0	12.9	-19%

Direct comparison is limited because the historical figures represent site-level averages rather than individual claim durations. In addition, the validation dataset was generated under pilot-study conditions rather than full operational deployment. However, the results suggest that the structured workflow may reduce investigation duration while also reducing variability in how cases are progressed.

10.2.2 Decision-making Framework

A second objective of the project was to reduce dependency on individual judgment by introducing a structured decision-making framework.

This validation exercise indicated good workflow adherence across participants. Required safety checks were completed in all cases, and only minor variations from the intended workflow were observed. Participants P1 and P3 performed additional testing during selected investigations, while Participant P2 followed the proposed route without unnecessary testing. The results suggest that the framework guided investigation progression across different experience levels, from experienced users to users with limited exposure to the workflow.

Engineer confidence scores ranged from 3.8 to 4.8 out of 5. The lowest score was recorded by the least experienced participant, suggesting that technical judgement remains an important element of warranty analysis even when supported by a structured process. However, all participants achieved valid investigation outcomes, indicating that the workflow provides sufficient guidance while still allowing engineering discretion where required.

10.2.3 Reporting Standardisation

The validation results reveal that the proposed reporting structure achieved greater consistency across users and claim types.

Reporting consistency received some of the highest feedback scores recorded during validation, ranging from 4.6 to 5.0 out of 5. Workflow clarity also received consistently high ratings, ranging from 4.6 to 4.9 out of 5.

Historically, reporting practices differed significantly between locations. Some sites relied heavily on photographs with limited written analysis, while others produced highly detailed narrative reports. The structured reporting format developed within this project provides a common framework for recording observations, test results, autopsy findings, and claim conclusions.

The positive feedback scores suggest that users were able to follow the reporting structure regardless of prior experience. Although the sample size was limited, the results suggest that the reporting framework was generally accepted by participants and may help improve consistency across sites.

10.2.4 Digitalisation and Structured Data Capture

A further objective of the project was to improve the capture, storage, and utilisation of warranty information.

The validation exercise demonstrated that claim information, failure modes, claim outcomes, and attributable processes could be captured using a common data structure and visualised through the integrated reporting dashboard. Although the pilot dataset was not intended to produce meaningful operational trends, it demonstrated that structured information can be transformed into searchable reports and visual dashboard outputs.

10.2.5 Operational Implications

The indicative labour assessment suggests that investigation effort remained linked to case complexity, although there was overlap between individual cases. Low-complexity investigations averaged approximately 15.0 labour hours and £274; moderate-complexity cases averaged 23.2 labour hours and £405, and high-complexity cases averaged 25.7 labour hours and £500.

The increase in average labour effort from low, to moderate, and high-complexity cases suggests that the workflow reflected the additional testing, interpretation, and reporting effort required for more complex investigations. However, the results also show that complexity was not the only factor affecting labour cost. Claim duration, reporting time, participant labour rate and the specific investigation route also influenced the final estimate. For example, case C27 produced the highest labour estimate at approximately 50.0 hours and £1000, due to extended investigation duration and a partial acceptance outcome.

The grouping of labour calculations within each complexity category suggests that the workflow provided a more repeatable approach to resource utilisation. Although the labour estimates are indicative rather than definitive costs, the results suggest that the proposed workflow may improve the predictability of investigation effort by reducing variation between users and locations.

Taken collectively, the findings indicate that the proposed workflow, decision-making framework, and reporting structure can support a more consistent and controlled approach to warranty analysis. While wider deployment would be required to fully evaluate operational performance, the pilot indicates that the objectives of improving standardisation, reporting consistency, and process control were largely achieved within the scope of this project.

10.3 Digital System Outputs

The digital system produced the intended outputs throughout the validation exercise. Reports were created, edited, and generated directly from information captured within the Power Apps interface, providing a consistent reporting format across all validation cases. An example generated report is shown in Figures 10.1 and 10.2.

EnerSys - Customer Claim Analysis

Claim Number: [REDACTED]
Date: [REDACTED]

Claim Description

Customer Name: [REDACTED]
Product Name: DataSafe 12XE1110F-FR Bloc (12V 1109Wh)
Quantity returned: 4
Serial Number: 2133 A 50005 / 2133 A 50159 / 2133 A 50181 / 2105 A 50298
Manufacturing Date: 2021-06-11

Problem Description

[REDACTED] Blocks failed discharge test during preventive maintenance inspection

Laboratory Analysis

On Receipt - Visual Inspection:
No visual issue found : blocs are not damaged nor leaking

On Receipt - Electrical Analysis:
bloc 2133 A 50005 : 13.05 V / 2.75 mOhms
bloc 2133 A 50181 : 13.05 V / 2.84 mOhms
bloc 2105 A 50298 : 12.97 V / 2.81 mOhms
bloc 2133 A 50159 : 12.86 V / 2.90 mOhms

Laboratory - Electrical Analysis:
We made a discharge in 12 minutes at 396 A to reach 1.67 Vpc (10.02 V per bloc).
bloc 2133 A 50005 reached 5.8 % capacity
bloc 2133 A 50159 reached 27.8 % capacity
bloc 2105 A 50298 reached 80.6 % capacity
bloc 2133 A 50181 reached 94.4 % capacity

Figure 10.1 - Example Generated Report: Page 1

All validation cases successfully generated both Word and PDF outputs using the automated reporting workflow. Reports followed a common structure regardless of claim type or engineer, ensuring observations, conclusions, and supporting information were presented consistently.

bloc 2133 A 50159:						
Total	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
12.97	2.19	2.17	2.19	2.17	2.20	2.03 V
2.62	0.44	0.46	0.46	0.45	0.48	0.55 mOhms
Cell 6 has been taken out and we did not see any manufacturing issue.						
bloc 2133 A 50181:						
Total	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
13.14	2.19	2.19	2.19	2.18	2.20	2.17 V
2.68	0.47	0.49	0.48	0.50	0.49	0.50 mOhms
No differences between the cells: none of them has been taken out because the capacity was correct: 94.4%						
bloc 2105 A 50298:						
Total	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
13.04	2.16	2.18	2.16	2.18	2.17	2.18 V
2.60	0.48	0.47	0.47	0.44	0.48	0.46 mOhms
No differences between the cells: we performed a new discharge test in the same previous conditions by checking the cells separately every minutes. Cell 2 is falling down to 0 V after 10 minutes of discharge.						
It has been taken out to a closer internal view, but no trouble has been found.						
Conclusion						
The four returned cells underwent a discharge test, where three blocks failed, and the last block showed a capacity close to 95%.						
Teardowns were conducted on the failed blocks, but no manufacturing defects were found to explain the observed capacity issues. Although one cell in one block had an inverted number of plates, this anomaly was not the cause of the issue.						
Claims Decision: Commercial replacement						
Actions Required						
Collect additional samples for laboratory analysis.						
Evaluate historical BMS records and system settings.						
[Redacted]						
[Redacted]						
Email: [Redacted]						

Figure 10.2 - Example Generated Report: Page 2

The automated workflow also successfully managed report updates. Where changes were made after report generation, existing outputs were automatically replaced with the updated versions, ensuring alignment between stored data and generated documentation.

In addition to report generation, structured data captured within the system was successfully visualised through the integrated Power BI dashboard. Failure modes, claim outcomes, and attributable process categories were categorised and displayed using standard visualisation tools. The dashboard output is shown in Figure 10.3.

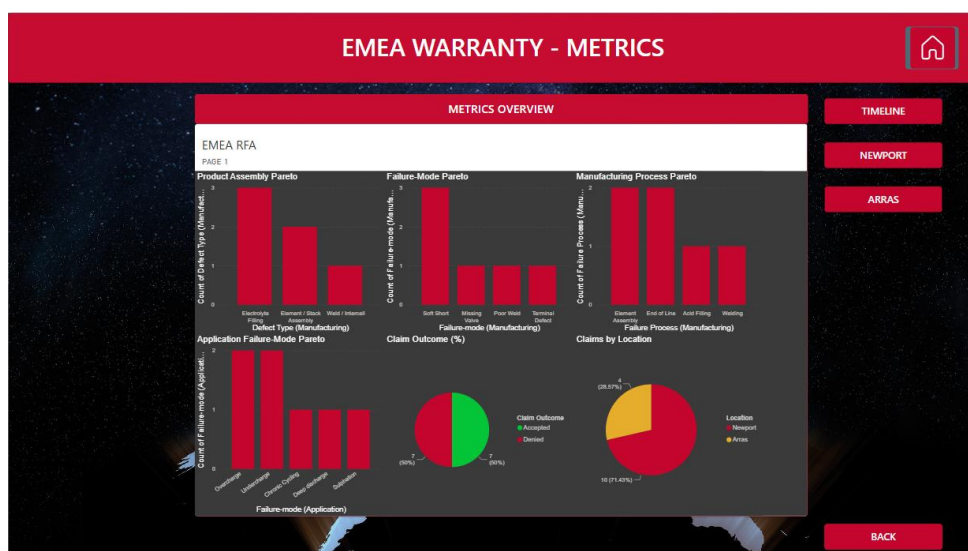


Figure 10.3 - Power Apps Dashboard Interface

Due to the pilot-scale nature of the validation dataset, these outputs should be considered demonstrations of reporting and visualisation capability rather than representative operational trends. However, the results demonstrate that structured warranty data can be captured, stored, reported, and visualised within a single integrated system.

The validation exercise confirmed that the proposed digital solution could support structured data capture, automated reporting, centralised storage, and basic analytical visualisation within the scope of the project.

11. Discussion and Conclusions

11.1 Study and Implementation Limitations

The findings should be considered in the context of several limitations relating to both the validation exercise and the implemented system.

Validation was conducted using three participants and thirty representative warranty cases. While this was sufficient to assess the workflow's practical operation and key trends, it does not provide a statistically representative assessment of long-term performance. In addition, the validation exercise was conducted under controlled conditions and therefore did not completely replicate the competing priorities, workload fluctuations, and resource constraints encountered in day-to-day laboratory activities.

A further limitation relates to comparisons with historical performance data. The historical dataset consisted of site-level average durations, whereas the validation results were generated from individual case studies. As a result, direct statistical comparison between the two datasets is limited. While the observed improvements suggest that the workflow may improve efficiency, the magnitude of the benefit cannot be determined accurately without a larger operational dataset.

The implemented system also has various technical limitations. Detailed electrical datasets are not currently captured in a standardised format, and certain information remains dependent on free-text user input. Consequently, data quality remains reliant on the completeness and accuracy of information entered by the investigator. Similarly, the current implementation uses SharePoint Lists rather than Dataverse, limiting the complexity of data structures that can be supported.

Finally, wider deployment would require additional refinement and validation. Although user feedback was generally positive, expectations regarding report content and presentation varied between stakeholders. Successful implementation would therefore require continued engineer engagement, further development of the reporting structure, and a longer-term operational trial to assess performance under normal working conditions.

Despite the limitations, the validation exercise demonstrated that the proposed workflow, reporting structure, and digital tools are technically viable and capable of supporting a more standardised approach to warranty analysis. The limitations identified should therefore be addressed through further development rather than viewed as barriers to implementation.

11.2 Discussion

11.2.1 Standardisation, Efficiency and Knowledge Transfer

The validation results suggest that the proposed workflow may improve both the consistency of outcomes and resource efficiency compared with the current approach. The average completion duration across the validation dataset was 13.7 days, compared with historical laboratory averages of 31 days in Newport and 16 days in Arras. Newport and Arras validation cases averaged 14.3 and 12.9 days.

These improvements should be interpreted cautiously. The historical values represent site-level averages, while the validation dataset consisted of pilot investigations completed under monitored conditions. Factors such as claim volume, equipment utilisation, competing laboratory priorities, and wider operational delays were not

represented. Consequently, the observed reductions of approximately 54% for Newport and 19% for Arras are likely to overstate the benefits achievable during full deployment.

The stronger finding is the apparent reduction in variation. The mean completion duration of 13.7 days closely matched the median of 13.5 days, while average durations increased with complexity from 9.4 days to 14.8 and 16.3 days. Although some overlap remained between individual cases, the overall trend implies that investigation effort was influenced more by technical complexity than by differences in user approach or local working practices.

This is supported by the workflow consistency results. All participants completed the required safety checks and generally followed the intended route, regardless of experience level. The least experienced participant recorded the lowest confidence score of 3.8 out of 5 but still completed investigations successfully.

Taken together, the results suggest that the principal benefit of the workflow may be consistency rather than speed alone. The process appears to formalise knowledge previously transferred through local practices and informal mentoring, creating a more structured, trainable approach to warranty analysis. This is consistent with the standardisation and knowledge-transfer literature discussed in Section 7.1, which shows that structured processes support consistency, traceability, and cross-site learning (ISO, 2015; Klippert et al., 2023).

11.2.2 Safety and Risk Reduction

Safety considerations were a key driver in the development of the workflow and influenced several decision points introduced into the process. The expanded visual inspection stage, controlled charge acceptance testing, and defined escalation routes were all intended to reduce the likelihood of unsafe investigation pathways.

While the validation exercise was not intended to systematically quantify safety improvements, the workflow introduces additional controls at stages where operational experience has identified increased risk. In particular, the requirement to assess leakage, physical damage, and severe discharge conditions before electrical testing provides a more consistent approach to risk management than relying solely on individual judgment.

The effectiveness of these controls remains dependent on correct use of the process and should therefore be viewed as an additional layer of protection rather than a replacement for existing safety procedures. Nevertheless, the workflow embeds safety considerations directly into the investigation process and provides a more structured approach to potentially hazardous testing activities.

11.2.3 Reporting, Data Capture and Digitalisation

Reporting consistency received some of the highest scores recorded during validation, ranging from 4.6 to 5.0 out of 5, while workflow clarity averaged approximately 4.8 out of 5. This suggests that users generally found the reporting structure predictable and easy to follow.

However, the reduction in administrative effort was less significant than initially anticipated. Although report generation was automated, users remained responsible for entering observations, conclusions, and supporting information manually. As a result, report quality and data quality remain dependent on the completeness and accuracy of information entered by the investigator. This was reflected in the validation dataset, where reporting time varied from approximately 0.5 to 2.0 hours depending on claim complexity and investigation requirements. Average reporting time increased from approximately 0.9

hours for low-complexity cases to 1.0 hours for moderate cases and 1.3 hours for high-complexity cases.

The findings suggest that the greatest value of the system may be structured data capture rather than reporting speed. This aligns with the Quality 4.0 and digitalisation literature discussed in Section 7.4, which presents digital tools as means to improve data availability, traceability, and process visibility (Carvalho et al., 2021; Sader et al., 2022). Failure modes, claim outcomes, and attributable processes were successfully categorised and visualised during validation, demonstrating that information can be captured consistently and converted into searchable outputs.

While the validation dataset was too small to generate meaningful operational trends, it demonstrated the potential for future analysis and knowledge sharing. Additional data validation, automated claim population, and AI-assisted reporting may further increase the value of the structured data created by the system.

11.2.4 Organisational Impact and Future Adoption

From an organisational perspective, the main operational implication is the potential reduction in investigation effort when the workflow is applied consistently. While the validation results showed reductions in completion duration relative to historical site averages, these values should be treated cautiously when considering long-term deployment performance.

The observed 54% reduction in Newport is unlikely to be fully representative of normal operational conditions. The validation exercise did not account for fluctuating claim volumes, equipment utilisation, competing laboratory priorities, or wider operational delays. A more conservative improvement of approximately 15% is therefore considered a more realistic assumption for wider deployment.

Using the indicative labour model developed during validation, and assuming 1.5 active labour hours per claim-open day, one hour of reporting time, and a representative average labour rate of £18/h, a typical Newport investigation based on the historical 31-day laboratory duration represents approximately 47.5 labour hours, equivalent to approximately £855 per claim. Applying a 15% reduction decreases this to approximately 40.4 hours or £727 per claim, representing a saving of approximately £128 per investigation.

Assuming an average workload of approximately 10 Energy Systems claims per week across Newport and Arras, this equates to an indicative saving of approximately £1,280 per week, £5,540 per month, and £66,560 per year.

These figures should not be considered a formal business case, as they are based on pilot-scale validation data and indicative labour assumptions. However, they demonstrate that even modest reductions in investigation effort can yield meaningful operational benefits when consistently applied across repeated warranty investigations.

The results also suggest that the value of the workflow extends beyond direct labour savings. Completion times remained grouped by complexity rather than user experience; standardisation may reduce the operational training burden, and all participants completed the required safety checks. Together, these findings suggest that the workflow may improve consistency, trainability, and process control alongside any efficiency gains achieved during deployment.

11.3 Conclusions

The aim of this project was to develop a more consistent and structured approach to warranty analysis through a standardised workflow, decision-making framework, and digital reporting system. Based on the findings presented, this aim was achieved to a significant extent, although further development is required before full operational deployment.

The review of existing processes identified variation in investigation duration, reporting methods, and decision-making practices across sites, providing a clear justification for a more structured approach. The project's strongest outcomes were the workflow and decision logic. Users with varying levels of experience were generally able to follow similar investigation paths, complete required safety checks, and achieve valid outcomes. This suggests that the main benefit of the workflow is improved consistency and trainability rather than speed alone.

The digital reporting system demonstrated structured data capture, standardised reporting, and automated document generation. However, this objective was achieved to a lesser extent than originally intended. Reporting consistency improved, but administrative effort remained dependent on manual data entry. As a result, the greatest value of the system appears to be the creation of structured data rather than the full removal of reporting effort.

The validation exercise showed that the proposed approach is technically viable and capable of supporting real warranty investigations. However, the study's limited scale means the results should be considered indicative rather than definitive. The project therefore demonstrates the potential benefits of a structured warranty analysis system while also highlighting the need for further validation, refinement, and organisational adoption before wider deployment.

The project's strongest outcomes include improved consistency, enhanced knowledge transfer, embedded safety considerations, and a foundation for future data-driven analysis across multiple laboratory locations.

12. Recommendations and Further Work

12.1 Extended Operational Validation

The most immediate recommendation is to validate the proposed workflow over the long term under normal operating conditions. Although the pilot study demonstrated that the system could be applied across a range of cases and users, it was limited to three participants and thirty representative claims. A longer deployment across multiple sites would allow the workflow to be tested against real workload variation, competing priorities, and day-to-day operational interruptions. This would provide a more reliable basis for judging whether the efficiency and consistency improvements observed during the pilot phase are sustained in practice.

12.2 Salesforce Integration

A second recommendation is integration with the planned Salesforce warranty platform. During validation, claim details still had to be entered manually, even though much of the core claim information already exists within warranty systems. Linking the reporting tool directly to Salesforce would reduce duplicate entry, improve data accuracy, and lower the remaining administrative burden. This is likely to be one of the most valuable next steps because the results showed that reporting consistency improved, but the amount of manual input remained higher than ideal.

12.3 Structured Data and Dataverse Migration

The current SharePoint-based structure is sufficient for a proof of concept, but it limits the amount of structured technical data that can be captured. More detailed electrical data, such as OCV, impedance, and discharge results, would be better stored in a relational format. Migrating to Dataverse would allow the system to support richer datasets and improve future analysis. This would also strengthen the reporting structure by making it easier to search, compare, and reuse technical information across larger claim volumes. Microsoft Dataverse is designed to store and manage data used by business applications, supporting more structured and scalable data management than a single list-based repository (Microsoft, 2026d).

12.4 AI-Assisted Reporting

A further improvement would be the use of AI-assisted report generation. The current system standardises report formatting, but users still need to manually enter observations, conclusions, and technical summaries. An AI-supported layer could help generate draft narrative content from structured inputs, reducing the time spent on report preparation while still leaving the final technical judgement with the engineer. This would be especially useful if the goal is to reduce administrative effort further without removing control from the user.

12.5 Expanded Analytics and Power BI

The Power BI dashboard showed that the captured data could be visualised effectively, but the validation dataset was too small to yield meaningful operational trends. Future work should therefore focus on expanding the dataset and developing the dashboard into a more complete analytical tool. With larger volumes of live data, the system could be used to identify recurring failure modes, site-level trends, and process bottlenecks, giving the captured data greater long-term value.

12.6 Continuous Workflow Refinement

The workflow should continue to be refined through live use. User feedback during validation showed that the system was generally well-received, but it also highlighted differences in reporting expectations and areas for improvement in the interface. A structured review process would help ensure that the workflow remains aligned with operational needs while still preserving the standardisation introduced by the project. This would also allow the process to adapt as business systems, reporting requirements, and laboratory practices evolve.

12.7 Expansion to Motive-Power Applications

Future work should consider adapting the workflow and reporting system for motive-power products. These were excluded from the current scope because their testing requirements, failure analysis methods, and reporting structures are more variable than those of Energy Systems products. A separate development cycle would allow the process to be adapted for these applications without compromising the clarity of the Energy Systems workflow developed in this project.

The most valuable future work is likely to come from wider deployment, stronger integration, improved data structure, greater automation, and expansion to additional product groups. The current system provides a credible foundation, but its full value will only be realised if it is developed into a more connected and data-rich operational tool.

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14. Appendices

14.1 Appendix A: Raw Validation Data

Table 14.1 - Raw Validation Data

Case ID	Participant	Product Type	Failure Type	Complexity	Claim Result	Completion Time (Days)	Reporting Time (Hours)	Total Labour (Hours)	Labour Rate (£/h)	Indicative Labour Cost (£)
C1	P2	Energy Systems	Overcharge	High	Rejected	17	1.25	26.75	£ 18.50	£ 494.88
C2	P1	Energy Systems	Bulging	High	Rejected	20	0.75	30.75	£ 20.00	£ 615.00
C3	P3	Energy Systems	Terminal corrosion	Low	Accepted	12	0.75	18.75	£ 15.50	£ 290.63
C4	P1	A&D	Over discharge	Moderate	Rejected	18	0.75	27.75	£ 20.00	£ 555.00
C5	P2	Transportation	Over cycling	Moderate	Rejected	13	1.25	20.75	£ 18.50	£ 383.88
C6	P1	Energy Systems	Soft Short	Moderate	Accepted	6	1.25	10.25	£ 20.00	£ 205.00
C7	P3	Energy Systems	Self-discharge	Moderate	Partial Acceptance	29	1.25	44.75	£ 15.50	£ 693.63
C8	P2	A&D	Welding defect	High	Accepted	10	1.25	16.25	£ 18.50	£ 300.63
C9	P1	Transportation	Leaking	Low	Accepted	14	1	22	£ 20.00	£ 440.00
C10	P2	Energy Systems	Undercharge	Moderate	Rejected	15	1	23.5	£ 18.50	£ 434.75
C11	P1	Energy Systems	Undercharge	Moderate	Rejected	10	1	16	£ 20.00	£ 320.00
C12	P3	Transportation	Soft Short	Moderate	Accepted	15	1	23.5	£ 15.50	£ 364.25
C13	P1	Transportation	Leaking	Low	Rejected	7	0.75	11.25	£ 20.00	£ 225.00
C14	P2	Transportation	Terminal corrosion	Low	Accepted	8	0.5	12.5	£ 18.50	£ 231.25
C15	P1	Transportation	Bulging	High	Rejected	13	0.75	20.25	£ 20.00	£ 405.00
C16	P1	A&D	No Fault Found	High	Rejected	11	1.75	18.25	£ 20.00	£ 365.00
C17	P2	Transportation	Self-discharge	Moderate	Rejected	14	1	22	£ 18.50	£ 407.00
C18	P2	Energy Systems	Loose Plate	Low	Accepted	9	1.25	14.75	£ 18.50	£ 272.88
C19	P2	Energy Systems	Lead Drip	Moderate	Accepted	13	1.5	21	£ 18.50	£ 388.50
C20	P3	Energy Systems	Overdischarge	Moderate	Rejected	18	0.75	27.75	£ 15.50	£ 430.13
C21	P1	Energy Systems	Soft Short	Moderate	Accepted	8	1.25	13.25	£ 20.00	£ 265.00
C22	P3	Transportation	Over cycling	Moderate	Rejected	14	1.25	22.25	£ 15.50	£ 344.88
C23	P2	Transportation	Leaking	Low	Rejected	11	1.5	18	£ 18.50	£ 333.00
C24	P2	Energy Systems	Micro-cycling	High	Rejected	20	2	32	£ 18.50	£ 592.00
C25	P3	Transportation	Mechanical Damage	Low	Rejected	5	0.5	8	£ 15.50	£ 124.00
C26	P3	Energy Systems	Undercharge	Moderate	Rejected	18	0.5	27.5	£ 15.50	£ 426.25
C27	P1	Energy Systems	End of Life	High	Partial Acceptance	32	2	50	£ 20.00	£ 1,000.00
C28	P2	Energy Systems	Undercharge	Moderate	Rejected	16	0.75	24.75	£ 18.50	£ 457.88
C29	P2	Transportation	Misaligned Cast	Low	Accepted	9	1.25	14.75	£ 18.50	£ 272.88
C30	P1	Transportation	Overcharge	High	Rejected	7	1	11.5	£ 20.00	£ 230.00

Table 14.2 - Summary of User Feedback

Feedback Area	Summary of Feedback	Response / Implication
Data availability	Users requested tabulated OCV and impedance reference data to support interpretation of electrical test results. Concerns were also raised regarding duplicated administrative information such as claim number, date, quantity and customer details.	The need for improved structured electrical data was identified as a future development requirement. Duplicated administrative entry was recognised as a limitation of the current system and could be reduced through future integration with upstream warranty systems.
Reporting structure	Arras users noted that the proposed reporting structure differed significantly from existing photo-based reporting practices. Director-level feedback also indicated that excessive image use can create issues during external review or customer discussion. Some users requested larger discussion fields to support more detailed narrative reporting.	The reporting structure was adjusted to balance visual evidence with controlled written explanation. The system retained image capture functionality but placed greater emphasis on concise and structured reporting. Additional reporting flexibility was identified as a future improvement.
User interface	Users requested improvements to page layout, navigation, view-page controls and icon clarity.	The interface was revised following feedback, with navigation controls and button structures adjusted to improve usability and reduce ambiguity.
Technical content	Clarification was requested regarding the charge acceptance testing methodology. Some users also felt that the visual inspection section was more detailed and standardised than current practice.	The workflow was refined to clarify controlled charge acceptance and to ensure that safety-related inspection steps were clearly defined before electrical testing.
Future development considerations	Users identified future opportunities linked to planned software migration, reduced duplicate data entry, and possible AI-assisted report generation using structured templates.	These points were carried forward into the recommendations, particularly Salesforce integration, structured data improvements, and AI-assisted reporting.

14.3 Appendix C: Power BI Visualisations

14.3.1 Dashboard Overview

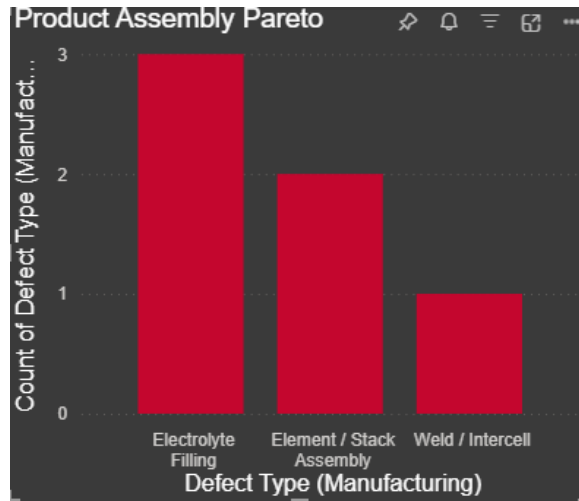


Figure 14.1 - Product Assembly Pareto

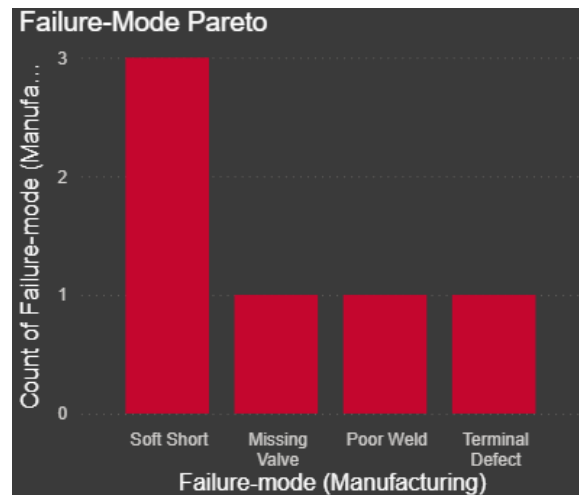


Figure 14.2 - Failure-Mode Pareto

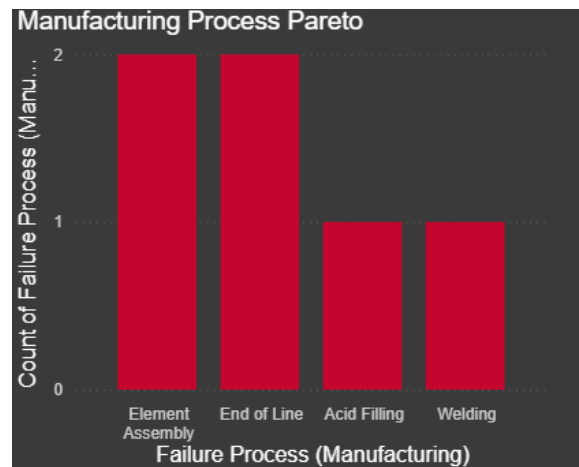


Figure 14.3 - Manufacturing Process Pareto

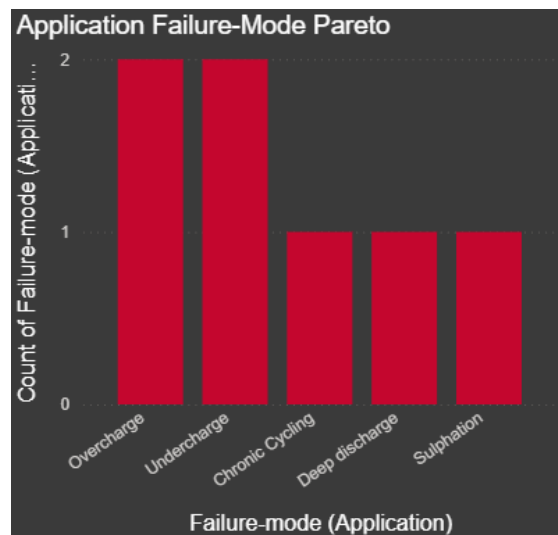


Figure 14.4 - Application Failure-Mode Pareto

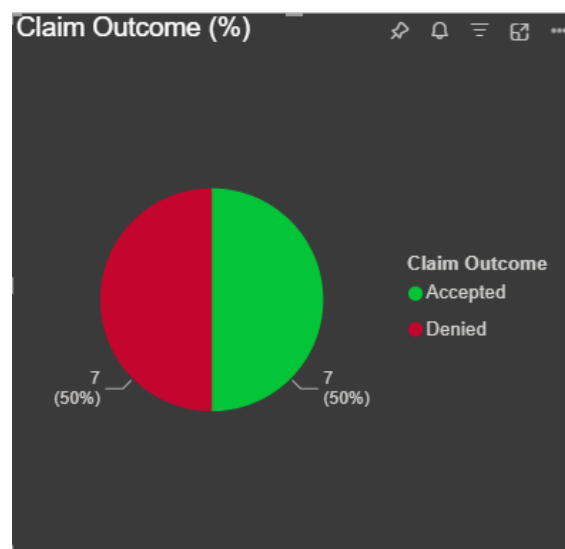


Figure 14.5 - Claim Acceptance (%)

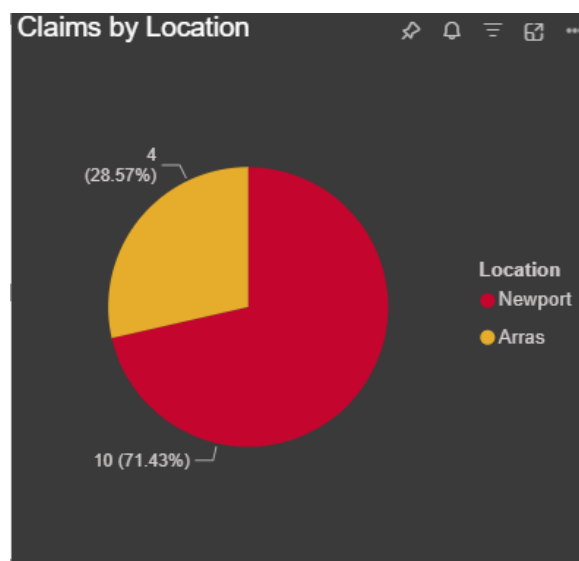


Figure 14.6 - Claims by Manufacturing Location