



Robert Lawton

Creation of a Plan for a Structured Data Collection System in a Semiconductor Manufacturing Environment

Metropolia University of Applied Sciences

Master of Engineering

Industrial Management

Master's Thesis

3rd May 2024

Abstract

Author: Robert Lawton
Title: Creation of a Plan for a Structured Data Collection System in a Semiconductor Manufacturing Environment
Number of Pages: 64 pages + 17 appendices pages
Date: 3rd May 2024

Degree: Master of Engineering
Degree Programme: Industrial Management
Instructor(s): Sami Sainio, Dr., Principal Lecturer
Sonja Holappa, M.A., Senior Lecturer

The objective of this thesis was to develop a plan for a structured data collection system for the semiconductor manufacturing site at Company X. The importance of structured data collection to create extensive data histories and subsequent analysis has been emphasised throughout the thesis.

After current state analysis of Company X's data collection techniques, the decision to create a new structured data collection system was agreed by all stakeholders. Data collection, system architecture, and platform development are researched to successfully create the architecture. Architecture creation is performed with the aid of the stakeholders to ensure user requirements are captured and change management purposes. An implementation plan to continue to the design stage of the application is also supplied.

The data collection system collects data from each manufacturing step; records engineering interactions; records batch histories; tracks batches during the semiconductor fabrication process; and enables engineering ad-hoc actions. Microsoft PowerApps is used as the software platform for the architecture as it meets the requirements for data collection; access control; functionality; and data analysis.

Beyond this thesis, the author must ensure that all engineers engaged with manufacturing data analysis know the value of the data. Data collected in a structured format ensures data quality, enabling automatic analysis immediately after generation, historic data analysis for improvement projects, and preventative maintenance.

Keywords and Definitions

Batch – Quantity of goods manufactured at the same time.

Graphical User Interface (GUI) – User interface which enables application users to interact with software, often by selecting predetermined software actions.

Key Performance Indicators (KPI) – Measurement data which provides key insights for performance, is often used to create targets for improvement or growth.

Manufacturing step – Refers to a manufacturing step where an operation takes place. Many steps create a manufacturing process.

Relational Database Management Systems (RDBMSs) – A database where data is stored and organised in predefined tables of columns and rows.

SharePoint List – A type of RDBMS within the Microsoft environment.

State – Refers to the stage within a step, which can either be waiting for track in, or, waiting for track out of that operation.

Statistical Process Control (SPC) – The use of statistical analysis to control and monitor production processes.

Contents

Abstract

Keywords and Definitions

Table of Contents

1	Introduction	1
1.1	Business Context	1
1.2	Business Challenge, Objective, and Outcome	3
1.3	Scope and Outline of the Thesis Report on Hand	4
2	Project Plan	5
2.1	Research Approach	5
2.2	Research Design	7
2.3	Data Plan	8
3	Current System Analysis and Requirements Gathering	9
3.1	Overview of Data Collection for Current State Analysis	9
3.2	Current Data Collection System in Company X	10
3.3	Analysis of Data Collection Workshop Findings	12
3.3.1	What is the current data collection system?	13
3.3.2	Do you routinely collect data from each manufacturing step?	13
3.3.3	How do you utilise data from each manufacturing step?	14
3.3.4	Does the current data collection system need improving?	14
3.3.5	How available is the data which is collected?	15
3.3.6	Other points discussed	15
3.4	Summary of Current System	16
3.5	Summary of Advantages and Disadvantages of Current Collection Methods.	16
3.6	Stakeholder Data Gathering for New System.	17
3.7	Requirements	18
4	Literature Review	20
4.1	Data Collection	21
4.2	System Architecture	23
4.3	System Platform Development	28

4.4	Conceptual Framework	30
5	Design System Plan	31
5.1	Defining Roles	32
5.2	Brainstorming	32
5.2.1	Brainstorming System Architecture	32
5.2.2	Brainstorming Data Collection Criteria and Human Error	36
5.2.3	Brainstorming Implementation of System	36
5.2.4	Summary of Brainstorming Workshop	37
6	Final Proposal	38
6.1	System Architecture	38
6.1.1	GUI Functionality Attribute Tables	40
6.1.2	GUI Module Overview	44
6.1.3	SharePoint Lists Overview	45
6.1.4	Workflow Example	47
6.1.5	Data Storage and Management	50
6.2	Data Collection and Management	51
6.2.1	Collection of Step Requirements for Data	51
6.2.2	Reuse of Data	51
6.2.3	Restrictions on Manual Data Input	52
6.2.4	Error Recovery	53
6.2.5	Monitoring, Management and Training	53
6.3	Stakeholder and Management Final Approval	55
7	Discussions and Conclusions	56
7.1	Executive Summary	56
7.2	Practical Next Step Recommendations	58
7.3	Self-Evaluation of Thesis Project Credibility	60
7.4	Closing Words	62
	References	63
	Appendix A – Initial Brainstorming Session	65
	Appendix B – GUI Functional Attribute Tables	65
	Appendix C – SharePoint Lists Variable Tables	74
	Appendix D – Final Proposal Presentation	76

1 Introduction

Data collection is paramount to all businesses. Whether the data collected is customer feedback for a restaurant or reading parameters off equipment at a semiconductor fabrication site, historical data helps determine future business decisions. Semiconductor fabrication sites rely on comprehensive process data collection systems to analyse faults, reduce waste, reduce costs, and improve quality and yield. Without a structured data collection system, a semiconductor company would fail to reliably deliver product to customers and ultimately lose market share to their competitors. An easily adaptable in-house data collection system can reduce manual data collection limitations enabling greater production gains.

1.1 Business Context

Company X produces semiconductors and is a subdivision of its parent company which uses these semiconductors in specialist products. The parent company is a multinational which specialises in analytical products that require niche technology. Company X has been an established subdivision for over 20 years and has developed several high-cost low-volume products. Figure 1 shows the structure of the parent company of Company X.

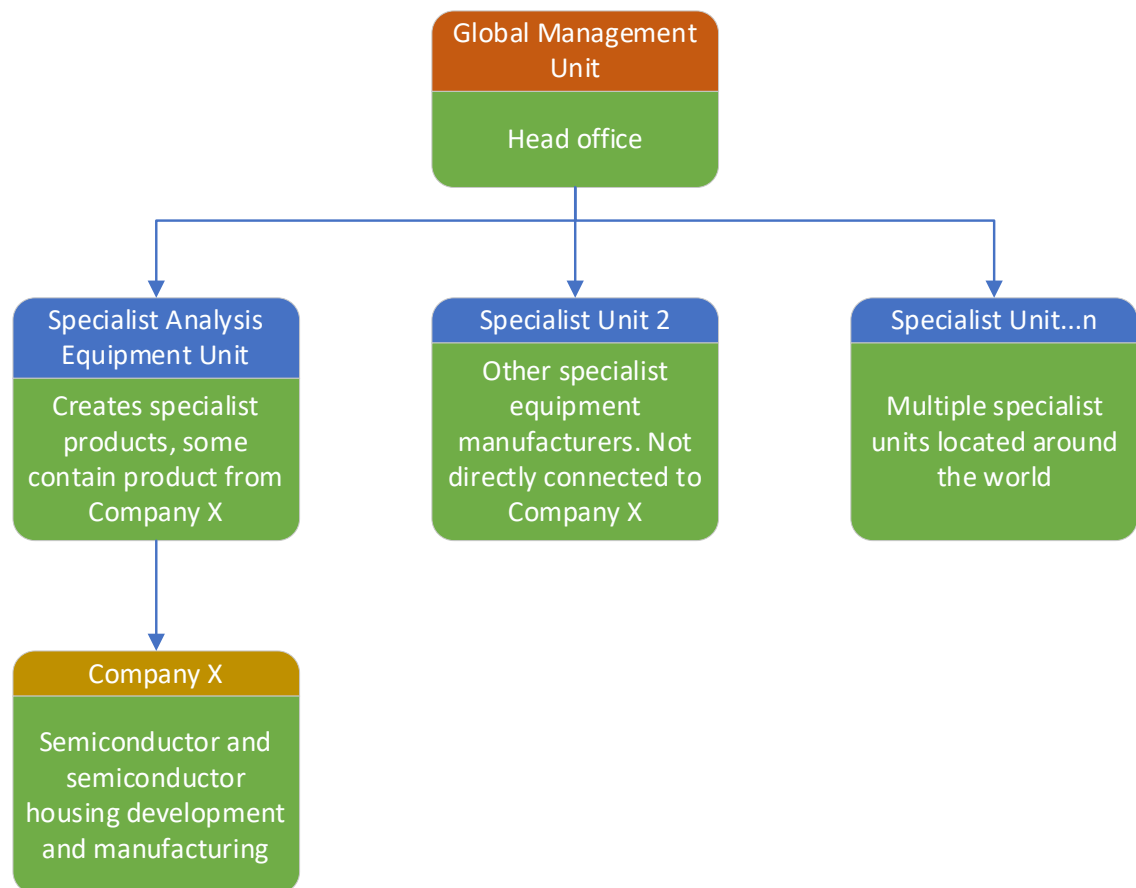


Figure 1 – Structure of parent company of Company X

As seen in figure 1 Company X's parent company is the Specialist Analysis and Equipment unit. Company X is divided into three main departments: development, production backend, and frontend semiconductor fabrication. The parent company has many different specialist units throughout the world, which specialise in developing and producing specialised high-tech equipment used in multiple industries. Although each unit is largely independent, communication occurs regularly between site directors, and resources are utilised globally when needed. The parent company's strategy is customer-focused and earning trust from all internal and external stakeholders while stepping forward to actively solve problems. The parent company strategy is the same for the other units including Company X. Figure 2 below depicts the hierarchical structure of Company X.

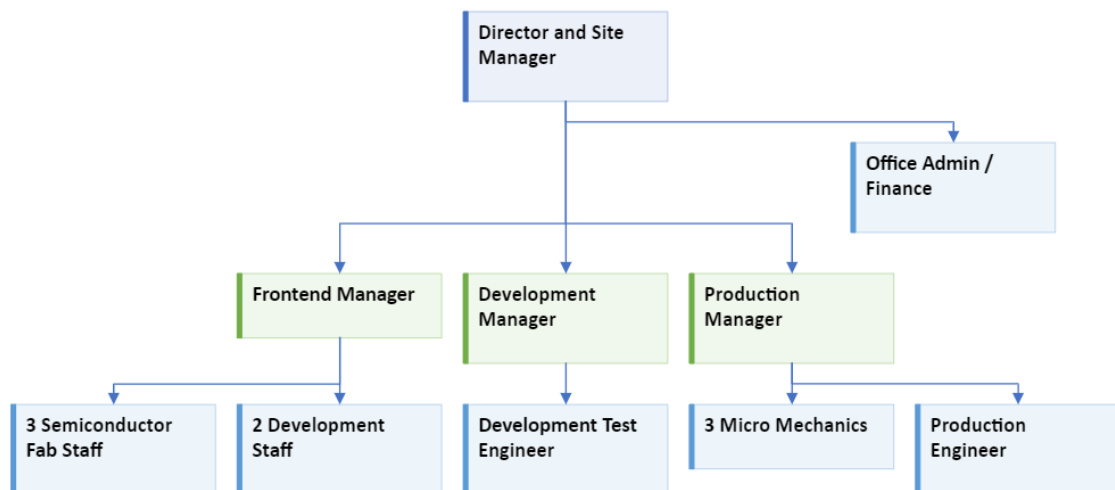


Figure 2 – Company X hierarchy

Figure 2 shows the hierarchical structure, some personnel are interdepartmental such as the production engineer. The scope of this thesis will be the frontend department where semiconductor fabrication takes place. The frontend department consists of one manager who is a development specialist, three fabrication staff, and two development engineers.

1.2 Business Challenge, Objective, and Outcome

Company X has developed a new product which can be produced in higher volumes than previous products. The frontend fabrication department does not have a structured data collection system to aid controlled production. Implementing a structured data collection system will aid the collection and analysis of data systematically, track product progress during fabrication, and enable users to easily create controlled product routes and histories. By fulfilling the data collection requirements, controlled production is possible. Controlled production aids on-time deliveries to customers in line with the companywide strategy.

The objective of this thesis is to develop a plan for a structured data collection system, to fulfil the requirements of the frontend team operating in the

semiconductor fabrication site. Therefore, the outcome will be a plan for the structured data collection system.

1.3 Scope and Outline of the Thesis Report on Hand

The scope of the data collection system is the frontend semiconductor fabrication department, and the data collection system will cover all manufacturing processes within semiconductor fabrication.

This thesis is split into seven sections. Section one introduces the case company and the study. The second section lays out the project plan and research method. Section 3 is the current state analysis, where a review of the current data collection system is undertaken, and current employees of company X provide feedback. The end of section 3 lists the three main subject matters, which will be used to carry out research to fulfil requirements found in the current state analysis. The literature review in section 4 researches the identified subjects; data collection; system architecture and platform development to create an initial plan in the next section. Section 5 is the initial structured data collection plan creation section; this details how the initial plan was created using sections 3 and 4 and further data collection with key stakeholders. Section 6 details the final proposal which is the combination of all previous sections to achieve the thesis objective. Finally, section 7 concludes the thesis with an executive summary, next-step actions, and self-evaluation.

2 Project Plan

Section 2 consists of the project plan on which the thesis is based. The first sub-section provides the research approach and justification for the approach used for the thesis. Research design is introduced next and details how the study was carried out, shown in a visual format. Next, this section shows how the research data was collected for the thesis and the justification for each data collection round with commentary on the types and significance of the data.

2.1 Research Approach

Research has many different approaches but referencing Kothari, 2004, its purpose is to discover answers to questions through the application of scientific procedures.

After reading literature from Kothari, 2004 the thesis author finds applied research and basic research to be frequently used research techniques. Applied research aims to find a solution to a problem facing a business. Pure research, also known as basic research, is used to further knowledge or to develop a theoretical understanding of a subject. Literature from Abbott et al, 2012 enforces Kothari's 2004 views which I summarise as; the purpose of pure research is not to respond to a specific research problem that requires an immediate answer.

This Thesis will use an applied research approach as it examines a practical solution for an existing problem. Table 1 below from Kananen, 2013 summarises different research approaches and methods further and lists their characteristics.

Factor	Research Approaches		Researches with Multiple Approaches Researches with Multiple Strategies		
	Qualitative Research	Quantitative Research	Case Research	Design Research	Action Research
Relationship between theory and practice	Induction or from practice to theory	Deduction or from theory to practice	Abduction	Abduction	Abduction or interaction between theory and practice
Purpose of research	Understanding	Generalisation, Prediction	Understanding	Change	Intervention Change
Researcher's role	External participant	External observer	External participant	External participant	Active actor
Researcher's questions	Open questions. Theme interview	Structured questions	Mainly open questions	Mainly open questions	Mainly open questions
Responses	Text descriptive	Numbers quantitative	Open	Open	Open

Table 1 – Classification of different research approaches and methods including their characteristics (Kananen, J. 2013).

Using table 1, I deduce the type of applied research for this thesis will be action research due to:

- Theory and practice interact, a theoretical basis for understanding concepts and ideas of data collection, practice allows implementation of these concepts.
- The purpose of research for the thesis is intervention and change, as the already existing data collection system is the target of improvement.
- The author's prior knowledge is utilised during research, they are an active actor.

Kananen, J. 2013:44 lists the following factors for action research:

- Development of operations (change)
- Cooperation
- Research
- Researcher participating in the change.

These factors are a clear fit for this thesis.

2.2 Research Design

The research design for the thesis in figure 3 shows the different stages of the thesis, their outcomes, and data collection requirements.

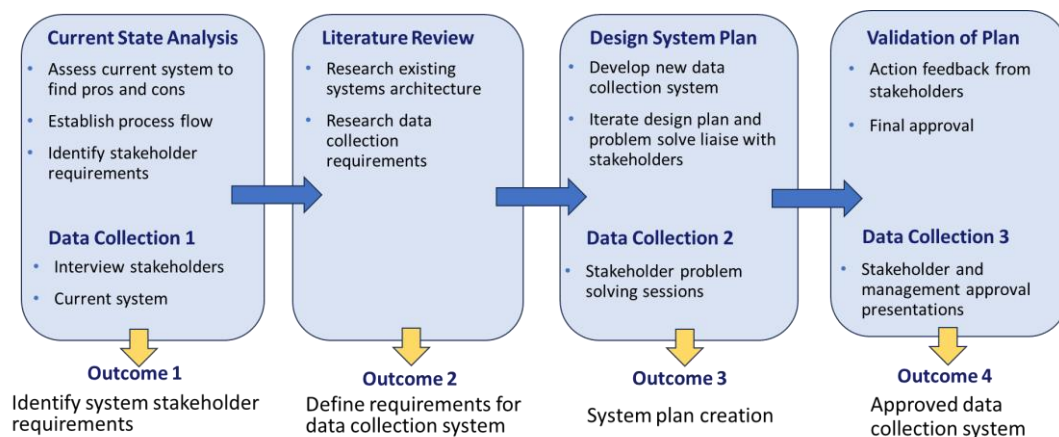


Figure 3 – Research design table.

The four main stages as shown in figure 3 are current state analysis, literature review, design system plan, and validation of plan. Current state analysis assesses the current state of data collection at company X and identifies stakeholder requirements. The literature review uses the requirements gained in the current state analysis to research and analyse data collection methods, data collection architecture, and ensures platform functionality with researched architecture. The design system plan uses the proposed solution driven from the list of requirements and the literature review to create a data collection platform design plan. Validation of the plan is the final approval by stakeholders and management.

2.3 Data Plan

The data plan for the thesis in figure 4 shows the different data collection stages of the thesis, use figure 3 to view where these data collection stages fit into the research design.

+ Data Collection 1 – Initial evaluation			
Content	Source	Timing	Outcome
Evaluation of current system pros and cons	Internal system and documents	January 2024 (some collection is from 2023)	List of current system pros and cons
Stakeholder requirements	System user stakeholder interview (5 people)	January 2024 (some collection is from 2023)	List of stakeholder requirements
+ Data Collection 2 – Teamwork to find solution			
Content	Source	Timing	Outcome
Iterate through different possibilities, problem solving to find best solution	System stakeholder interviews and other communication	March 2024	Best solution realised Data collection system plan ready to be finalised
+ Data Collection 3 – Final Plan Approval			
Content	Source	Timing	Outcome
Plan presentation and approval	System stakeholders and Management presentations	April 2024	Plan approved

Figure 4 – Data Plan

Figure 4 shows the three data collection steps, each step displays the content, source, timing, and outcome. Data collection 1 in the current analysis stage uses internal documentation and stakeholder interviews to gain analysis of the current system and a list of system requirements. Data collection 2 in the design system stage uses stakeholders' input to continually develop the data collection plan system. Data collection 3 collects data from stakeholders and management to make final amendments to the proposed data collection system and finally approve the proposed data collection system.

3 Current System Analysis and Requirements Gathering

Section 3 covers current state analysis and requirement gathering. Current state analysis assesses the state of the current data collection system to gain its advantages and disadvantages. The current state analysis will then be used to direct the literature review approach defining key research topics, which will be based on the requirements of an improved or new data collection system.

3.1 Overview of Data Collection for Current State Analysis

To gain insight into the current process and how data is handled when a product is processed through manufacturing steps at company X, a workshop was organised followed by interviews to gain the frontend staff's knowledge. The frontend staff consists of a manager and five operators, with three operators being production-orientated and two development-orientated. No other personnel are directly involved with the current data collection process. Table 2 below shows the different workshops/interviews.

Type	Attendees	Format	Interaction
Workshop	Manager, Operator 1, and 2	Semi-structured	Face to face
Interview 1	Operator 3	Semi-structured	Face to face
Interview 2	Operator 4	Semi-structured	Face to face
Interview 3	Operator 5	Semi-structured	Face to face

Table 2 – Workshop/Interview attendance and structure.

Table 2 shows the workshop only consisted of two production-orientated operators and the manager, but the remaining members of the frontend staff had individual interviews. A formal semi-structured workshop and interview

approach was taken, as the previous knowledge the author has gained in data collection will aid the structure of the workshop/Interview. Fully structured interviews/workshops were not chosen, to encourage operators to engage and ultimately give their opinions to the author and map out the current data collection system. Often within larger group workshops, the stronger speakers come through but not necessarily with the best ideas.

Face-to-face, email, telephone, and online meetings for workshops and interviews were all available options. Both interviews and workshops were face-to-face. Face-to-face gives higher interaction with the operators, as body language and personal interaction can aid the outcome which is not possible with email or telephone.

3.2 Current Data Collection System in Company X

Table 3 shows the documents assessed in the workshop which form the current data collection system in Company X. Figure 5 below shows the current process map for general product processing and the subsequent data collection method. This data is presented before the analysis to aid understanding of the subject matter but was drafted during the workshop.

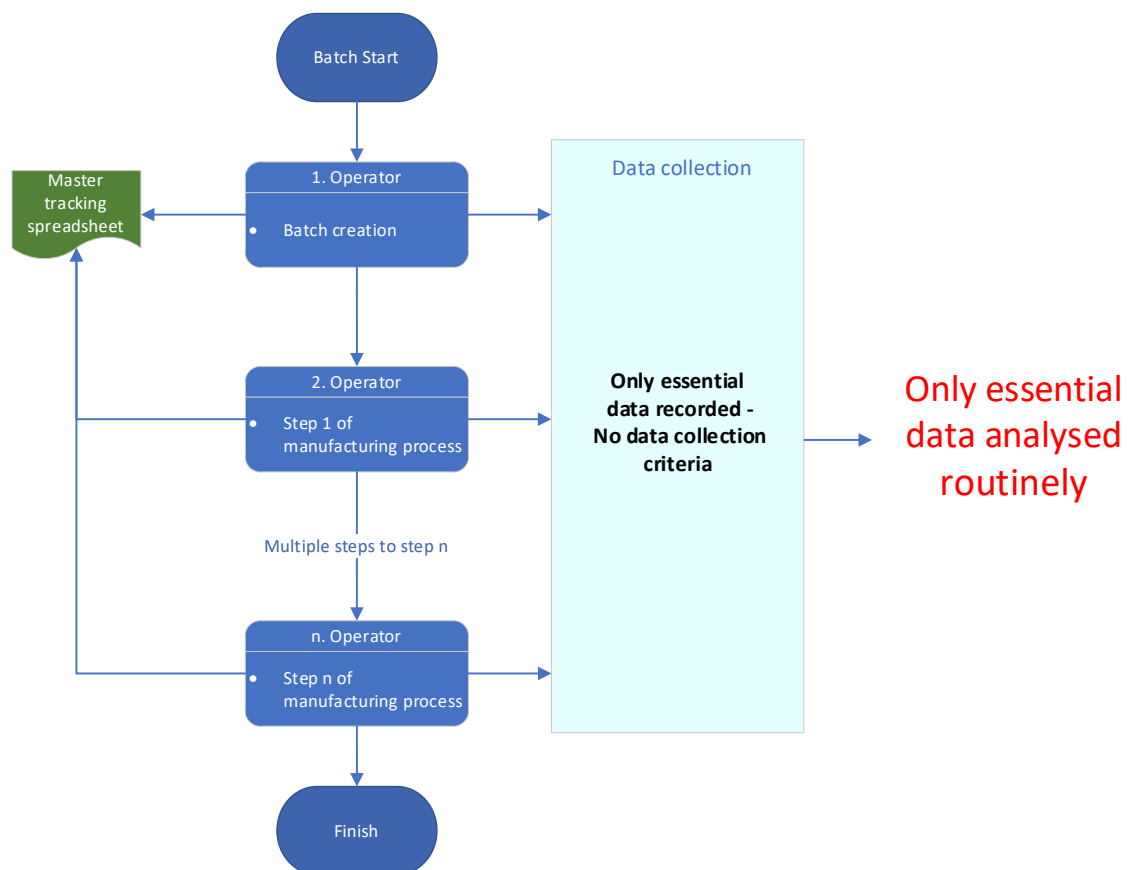


Figure 5 – Current data collection process flow

The dark blue shapes in figure 5 show the general process flow of manufacturing product X. The light blue box indicates an unorganised system of spreadsheets kept by the operators as detailed in table 3. The Master Tracking spreadsheet tracks the product and is common to all users. There are around 50 steps in the production of product X, each step generating different step data which is stored in different places by each operator. The step data is also detailed in table 3 below.

Document Name	Description	Manufacturing Steps	Users	Location
Master Tracking Spreadsheet	Records essential process data and batch step location	All	All – Including Manager	Common SharePoint site
Operator 1 Spreadsheets	Collects detailed step information	Not all steps are covered.	Operator 1, and other operators	Common SharePoint site
Operator 2 Spreadsheets	Collects detailed step information	All steps covered	Operator 2	Common SharePoint site
Operator 3 Spreadsheets	Collects detailed step information	Not all steps are covered	Operator 3	Personal SharePoint site

Table 3 – Documents forming the current data collection system.

Table 3 is an example of the situation as actually finding all the different spreadsheets added no value to the current state analysis. No routine analysis of data is performed on the data collected. The key pinch point of the current process is the approach to data collection and its utilisation. Table 3 shows there is no data collection criteria for step data.

3.3 Analysis of Data Collection Workshop Findings

To map and discuss the current data collection system, questions were created to be posed to the team to aid the workshop/interviews. These questions are detailed below but a large amount of information came from unscripted discussions, as planned by the semi-structured approach.

Question 1 – What is the current data collection system?

Question 2 – Do you routinely collect data from each manufacturing step?

Question 3 – How do you utilise data from each manufacturing step?

Question 4 – Does the current data collection system need improving?

Question 5 – How available is the data which is collected?

The subsections below detail the answers to the 5 questions posed and the author's analysis. The subsequent subsections continue to detail and analyse other information from the workshop/interviews which was not scripted.

3.3.1 What is the current data collection system?

This is covered in table 3 and figure 5 and their descriptions. Operator attitude towards production data collection seemed insufficient in comparison to other manufacturing sites the author has experienced. The insufficient attitude is mainly due to Company X focusing on development work and not having a background in production data engineering techniques. Although a current data collection system was mapped out, the only reasonably maintained document is the Master Tracking spreadsheet. Training will be needed to ensure a more proactive approach to data collection and analysis in the future.

3.3.2 Do you routinely collect data from each manufacturing step?

Operators collect data from steps they deem important enough to document in their spreadsheet, this means data is not collected from every manufacturing step. There is no data collection plan and no way of forcing operators to collect data. Only step process details that are essential to subsequent manufacturing steps are recorded.

Step data should be collected routinely and according to a data collection plan. This way statistical analysis can be performed and used to identify step issues and improvement projects to increase yield. Some operators are aware of the importance of such data collection but have failed to take up the issue due to prioritising other tasks. Development operators are not too concerned with day-to-day step data collection and only record data they need for their current projects, despite the significance of historical data when developing products. Process details and batch history should be collected to aid traceability for future manufacturing improvement and problem-solving.

3.3.3 How do you utilise data from each manufacturing step?

This question was presented to gain insight into how the step data is used by operators during manufacturing and after manufacturing when dealing with batch yield issues.

Operators measure products during some steps and compare the data to specifications but do not necessarily record the data. No step statistical process control (SPC) analysis is performed at any stage. Most operators admitted when investigating low-yielding batches that data was missing and therefore investigation into manufacturing issues was difficult.

No key performance indicators (KPIs) are set in the manufacturing process route, as lack of data collection makes meaningful KPIs difficult to define. Due to the lack of knowledge of SPC which KPIs would usually be based on, the operators did not discuss KPIs and SPC further.

SPC is needed to keep processes repeatable. Well-maintained SPC charts and analysis of SPC charts will give greater process understanding and contribute towards higher yields. In the current data collection system, data analysis is only attempted when failure occurs, and minimal process control is exercised with only upper and lower specification limits checked. There is a massive opportunity for improvement here gaining process knowledge and improvement and ultimately yield.

3.3.4 Does the current data collection system need improving?

As the author can provide insights into the benefits of a structured data collection system from experience, the author was able to promote the need for a new system. The structured data collection system concept was met with strong support except for one operator who did not seem concerned but was not negative. With this overall positive approach, the author does not see change resistance being a major issue in introducing a structured data

collection system. All the operators are engineers and thus the assimilation of new knowledge should not be an issue.

3.3.5 How available is the data which is collected?

Operators save data to their own process data spreadsheets and mostly in communal SharePoint locations. In the instances where operators would save their spreadsheet on a personal SharePoint location, they would be forthcoming with the data if asked. The issue is that operators do not know what data other operators will or will not record which makes meaningful data analysis difficult or impossible.

Not only should data be collected systematically but it should also be available to analyse. Data should be presented and accessed in such a way that routine analysis can be performed quickly if not automatically by connected software. Operators/Engineers need to be familiar with a structured system, so when problem-solving, they know what data is collected and can proceed with ad-hoc analysis without being held back. If required data is not available when needed for analysis, then collection of this data could be considered as an improvement for the structured data analysis system if the data is not too niche.

3.3.6 Other points discussed

Spreadsheet corruption – Operators stated that the spreadsheets are often mistakenly corrupted, which could cause the misprocessing of a batch if the corruption is in the Master Tracking spreadsheet.

Master Tracking spreadsheet – This document was utilised by all operators and tracks the location of the batch well if updated correctly and not corrupted. Operators stated that there is no accountability for the data entry and therefore operator step processing traceability is also not collected. Accountability is necessary to identify issues related to operator performance, without

accountability, it is difficult to identify operator mistakes and error-proof against them.

3.4 Summary of Current System

The site has been mainly focused on development work until recently and this shows in the current state of the data collection system. A structured data collection system which would then complement an analysis system, would enable the uptake of process control and improvement projects based on data.

The quality of data is low, no data collection plan exists, data is easily corrupted and there is no accountability for data collection. The low quality of data makes data analysis challenging, if not impossible in some situations, so manufacturing issues take much longer to rectify if identified at all.

A positive finding is that all operators are engineers, so any future uptake will be aided by previous data knowledge and mathematical skills. Operators who have never utilised data collection for process control should be able to grasp the concept quickly. Operators do not currently have a proactive approach to data but aided with a structured data collection system and the desire expressed in the workshop that one is needed, this approach to data will change.

It is easy to see opportunities for improvement of the current data collection system. Currently one might say that the current system is not really a system at all, the only functional part is the batch tracking system. It is likely with the author's previous expertise and the research to be conducted in this thesis a new system will be started from scratch.

3.5 Summary of Advantages and Disadvantages of Current Collection Methods.

Table 4 below summarises the advantages and disadvantages of the current data collection.

Advantages
Batch tracking is utilised
Known software (Excel)
Essential data is recorded (cannot process without)
Process data is check against specification (may not be recorded)
Disadvantages
Data stored in multiple places for each step
Not all data is openly shared
No routine data analysis performed after each production step
Incomplete data undermines any analysis performed
Not all step data collected
Data can be corrupted easily by human error in tracking sheet and step data collection sheets
Operators have no accountability for their actions
Most operators do not understand the value of improving the data collection system
Most operators do not have experience of structured data collection systems
Most operators do not know or use data analysis techniques such as statistical process control (SPC)
Data analysis is only performed when failure has occurred
No mapped out structure
Data collected is in different formats
No KPIs based on data collected

Table 4 – Advantages and disadvantages of the current data collection

When planning the new data collection system, table 4 should be referenced to ensure all as-is current state analysis findings are addressed, and either accommodated in the plan or their effects considered.

3.6 Stakeholder Data Gathering for New System.

Data gathering of requirements for the new data collection system was performed in the same sessions as the current state analysis, detailed in table 2. Although requirements for a new system came through during discussions, the author's experience in data collection proved to be more influential.

Many operators had no knowledge of previous structured data collection systems so failed to envisage the potential these systems hold. To the author's benefit, the operators who had experienced such systems expressed a desire for implementation. This type of influence will prove key to the change management aspect of this thesis, and also beyond the scope of the thesis when the implementation of the system is performed. Table 5 below summarises improvement ideas gathered while in the workshop/interviews. The author offered some improvement ideas during the sessions to enable some of the operators to gain a better understanding of how a structured data collection system functions and its benefits.

Issue	Improvement Idea	Who
Data quality	Force data entries at each step.	Operator 2
Lack of structured system	Integrate data collection with the tracking process	Operator 1
Utilisation of data for analysis	Create batch histories and other data queries.	author (during workshop)
Lack of structured system	Create process step data sheets for step data analysis such as SPC.	author (during workshop)
Lack of structured system	Create data collection plan.	author (during workshop)
System efficiency	New system to have group batch processing	Operator 5
Data integrity issue	Data should not be accidentally corruptible (access rights)	Operator 2

Table 5 – Improvement ideas for the new data collection system

Key to successful implementation is to satisfy the operators requests, but table 5 only provides a glimpse of what is needed from the new data collection system.

3.7 Requirements

Using the author's prior knowledge in data collection and data gathered in the current state analysis, key requirements were generated. These three requirements are general topics for research and will be used to fulfil the design

of a new data collection system including the disadvantages identified in the current system and the suggestions.

Data collection criteria

Data collection format must be structured with future analysis in mind; therefore we must determine what data is needed for analysis.

System architecture

The input system needs to cover both batch tracking and data gathering with minimal input but with maximum data collection. Research will be performed to ensure optimal architecture is used.

System Platform Development

Company X has a small fabrication site with no machine automation. Selecting the correct platform for cost-effectiveness and criteria fulfilment is crucial. The platform selection occurred outside the scope of this thesis, but the limitations of the selected platform will need to be taken into consideration when designing the architecture. The platform for the new data collection system will be Microsoft PowerApps.

4 Literature Review

Section 4, the literature review section will further clarify the requirements needed for the data collection system focusing on the three main topics listed at the end of the last section. Therefore, the research will be based on; data collection; system architecture; and system platform development.

To understand more about the design requirements of the data collection system, figure 6 below shows how data is used in a continuous improvement cycle in manufacturing environments the author has been previously employed.

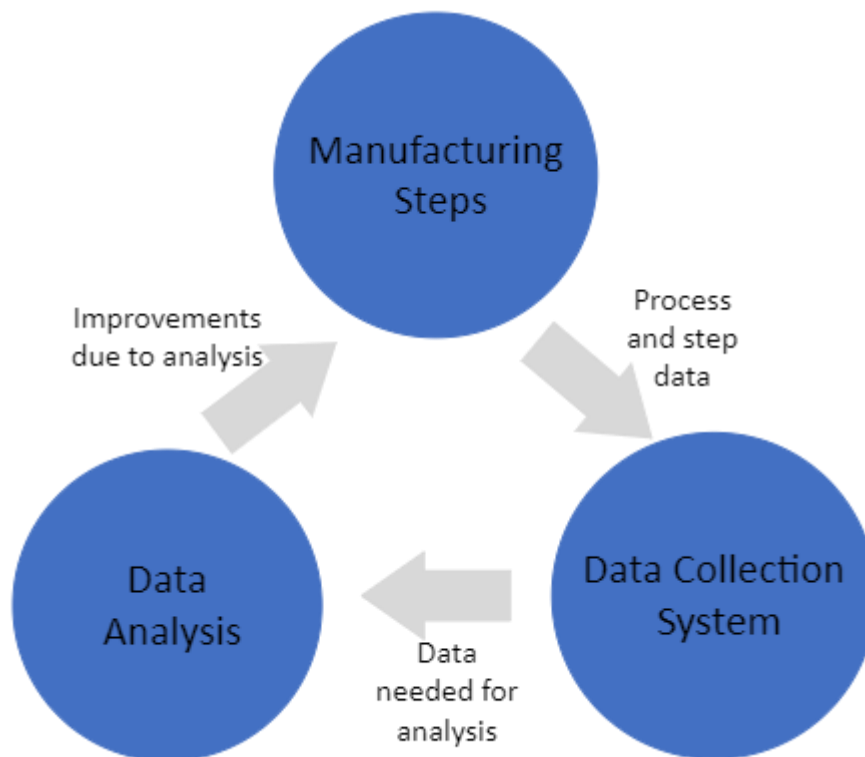


Figure 6 – Data collection for continuous improvement

Although figure 6 is a simplistic overview of the continuous improvement environment it aids reasoning for the thesis objective.

4.1 Data Collection

Data collected by a data collection system from the manufacturing steps (step data and measurement data) is used for data analysis as shown in figure 6. It is key to a data collection system, that the data is in a format that can be utilised by the analyst or analytic software and is of good quality. The author's experience in analysis and the manufacturing environment means that statistical process control (SPC) is identified as a key analysis tool.

The father of SPC is Walter A. Shewhart, but in the 1939 book 'Statistical Method from the Viewpoint of Quality Control' the data collection aspect of SPC is overlooked and the collection of quality data for each event is assumed. This assumption was perhaps understandable in 1939 before computerised data collection systems. Today's analysts rarely collect the data themselves and instead rely on computerised data collection systems such as a manufacturing execution system (MES).

When considering other data analysis methods, King (2017) mentions that although there are commonly used distributions such as those described as uniform or normal (Gaussian). There are in fact over 250 published distributions the majority of which are offspring from a much smaller number of parent distributions.

It can be seen from the above research and prior mathematical knowledge that defining the data to be collected from manufacturing steps and ensuring it is in a format that is ready to be used for analysis is a key requirement. We need not concern ourselves at this point with which analysis is performed after data collection but instead focus on what data is collected and its format.

Manufacturing steps that contain measurements need to capture each measurement outcome and not an average, any mathematical action on the collected data will be performed at the analysis stage which is not covered in this thesis.

George (2005) provides a template for a data collection plan, shown in figure 7 below.

Data Collection Plan

Metric	Stratification factors	Operational definition	Sample size	Source and location	Collection method	Who will collect data
How will data be used?				How will data be displayed?		
Examples: <ul style="list-style-type: none"> • Identification of largest contributors • Checking normality • Identifying sigma level and variation • Root cause analysis • Correlation analysis 				Examples: <ul style="list-style-type: none"> • Pareto chart • Histogram • Control chart • Scatter diagrams 		

Figure 7 – Data collection plan (George, 2005)

Figure 7 shows a simple table that is designed to interact with the analysis of data defining sample size and other important factors for each process step. Such data collection tables will be needed to define inline analysis for statistical process control but not needed for the data collection system itself except for sample size. A modified version of the data collection table in figure 7 will be used to define what data is collected within the structured data collection system.

The current state analysis showed the need for a structured data collection system to have data integrity and quality. Kleppmann (2017) covers human error and how to ensure systems are reliable in the five bullet points below.

- Minimise the opportunities for error by designing the opportunities out.

- Decouple the places where the most mistakes are made from the places where they can cause failures.
- Human error can be rectified easily and quickly to minimise impact.
- Monitor metrics such as performance and error rates.
- Implement effective management techniques and training.

The above will be considered when designing the architecture. To truly tackle the data collection aspect of this thesis options within the system platform will be explored to improve data quality.

4.2 System Architecture

Referencing Richards et al., (2020) to explain system architecture, the difference between architecture and design needs to be defined for the thesis. Where does architecture end and design begin? To think like an architect, you must know the difference between architecture and design and how they integrate to form solutions to technical problems. Figure 8 below gives a visualisation of the difference between architecture and design which is also provided by Richards et al., (2020).

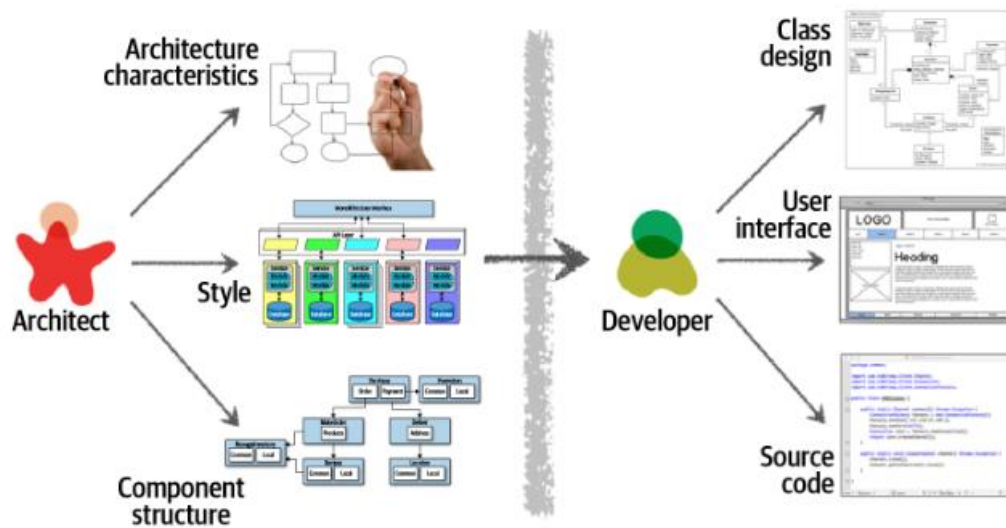


Figure 8 - Traditional view of architecture versus design (Richards et al., 2020)

Figure 8 shows that the code of the software need not be defined at the same time as the architecture. The scope of this thesis is the architecture but not the code, although the author may consider creating shell user interfaces for clarity.

Referencing Serra (2024), data architecture can be defined as a data architecture framework at a high level as organizing and managing data to support objectives. To do this involves defining how data is collected, stored, processed, and accessed, as well as maintaining data quality, security, and privacy. While data architectures can take many different forms, some common elements include:

Data storage – How data is stored, such as hard drives or cloud storage.

Data processing – How data is processed, including any transformations or calculations that are performed on the data before it is stored or analysed.

Data access – User interfaces and application program interfaces (APIs) that enable data to be queried and analysed.

Data security and privacy – Security and privacy of data, such as access controls, encryption, and data masking.

Overall, data architecture needs to enable an organization to manage its data so it can be used effectively to support objectives and decision-making. Serra's, (2024) take on the main goals of a data architecture provides valuable insight into the power of effective data collection. In the case of Company X, the business objective (beyond this thesis) is process improvement, planning, and process control. The decision-making process enables the production line to continue with minimal downtime due to effective process out-of-control response due to having a data structure that is 'ready to go' for analysis.

The importance of architecture must be understood if quality architecture is to be created. Bass et al., (2013) gives thirteen reasons some of which are summarised below.

- Architecture restricts or enables the system, enforcing quality attributes.
- Architecture allows you to plan and manage change as the system evolves.
- Analysing the architecture shows the potential system qualities.
- A well-documented system architecture improves communication with stakeholders.
- The architecture contains the fundamental design decisions that will be difficult to change once the system is implemented.
- An architecture defines the constraints for implementation.
- The architecture defines the structure of an organisation, or vice versa.
- An architecture can provide the basis for developmental prototyping.
- An architecture can be a transferable or reusable model that forms the basis of a product line.
- Architecture-based development focuses on component assembly instead of just component creation.
- An architecture can be the primary material used for training new team members.

Furthermore, Bass et al., (2013) defines some structural rules of thumb for architecture quality, some of these rules of thumb are outlined below.

The architecture should have well-defined modules functioning off assigned principles that hide and separate the concerns of each module. This promotes modules functioning individually which can promote understanding of the system and increase the ease with which the system can be modified.

Quality attributes are defined using known architectural patterns specific to each attribute. Establishing patterns aids design, functionality, and understanding of the system.

Modules should either produce data or consume data. This aids system modifications and gives upgrades a staged approach when needed.

The architecture should contain minimal ways for different components to interact. By reducing the ways in which components interact you simplify the architecture, promote understandability, improve reliability, and boost modifiability.

The above overview of Bass et al., (2013) structural rules of thumb will be used where possible when creating the architecture for the structured data collection system.

The system architecture should be functional. Bass et al., (2013) describes functionality as the ability of the system to do the work for which it was intended. A system must function as functional units coming together to achieve a task such as the many different types of engineers coming together to build a space rocket. Each unit must be assigned the correct tasks and links with other units or the whole system will not function.

Many different structures are available to achieve functionality. Functionality could be achieved as one complex unit but to aid understanding, maintainability, and creation of the system it is broken into many modules.

Implementation will also be covered in an implementation plan for the next phase after the structured data collection plan is complete. Figure 8 shows the approach by Bass et al., (2013) to the delivery of software. Figure 8 shows the software concept linking to preliminary requirements analysis and how they feedback to each other. Similarly, figure 8 shows preliminary requirements analysis linking to the design of architecture. Figure 8 then shows how the development of software iterates with feedback and interactions until the feedback is exhausted or the customer agrees to finalise.

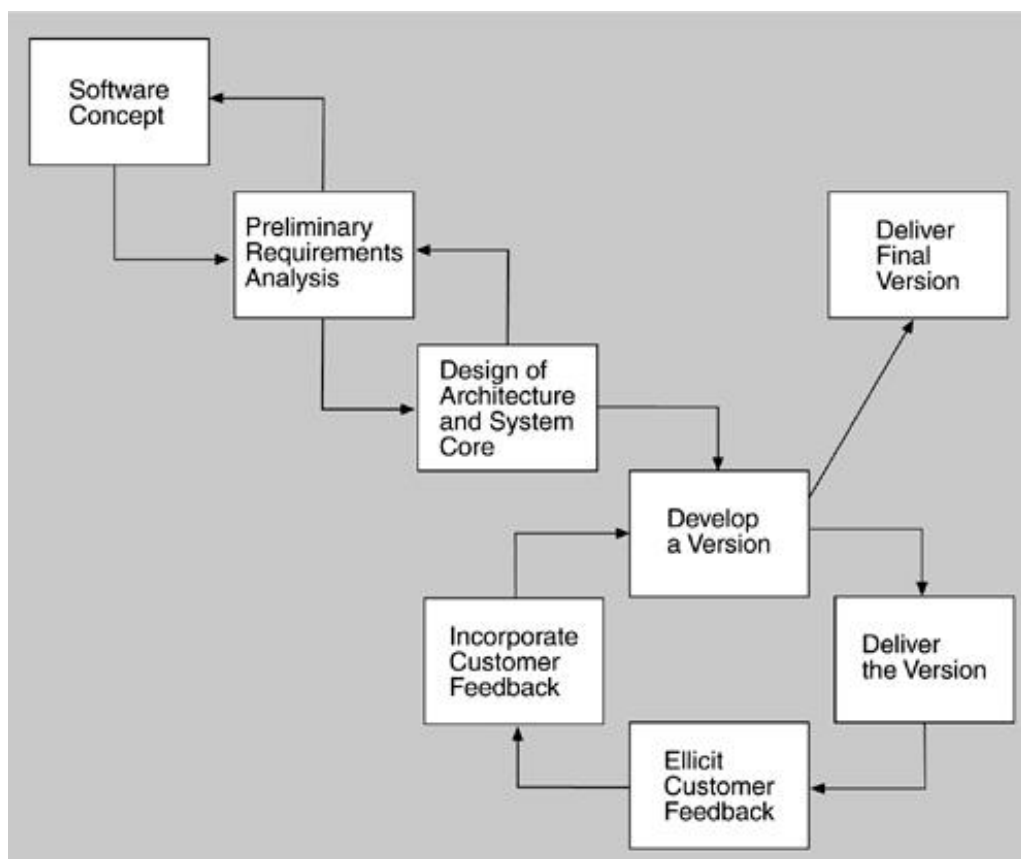


Figure 8 - Evolutionary Delivery Life Cycle (Bass et al., 2013)

Figure 8 gives a basic structure to deliver software that can be utilised in this thesis, but instead of delivery of completed software, the delivery will be a plan to implement new data collection software. This thesis will follow the steps up to the 'design of architecture and system core' and then iterate to improve the architecture instead of developing the software.

Meyer et al., (2009) is referenced for the implementation strategies below:

- "Big Bang"
- Step-by-step implementation in separate operating areas
- Step-by-step replacement of separate business processes

The "big bang" strategy implements the new system to all affected operations at the same time by a certain deadline. This "big bang" strategy comes with the risk that such large-scale implementation might affect multiple areas if the system has errors.

Step-by-step implementation in individual operating areas would implement the new system for one manufacturing step at a time reducing the risk of error. This can also stagger the training for different operators to coincide with implementation in their area. Step-by-step replacement of individual business processes isn't relevant in this thesis as the new system only covers one business process area.

An implementation strategy must be defined in the data collection plan so the next stage of implementation can proceed.

4.3 System Platform Development

Having termed the words 'structured data collection system' so far in this thesis maybe the author should explore exactly what structured data is. Tarantino (2022) mentions structured data which usually resides in relational database

management systems (RDBMSs). The structure of RDBMSs supports data searches by having a predefined structure such as row, column, tab, sheet format of a spreadsheet. RDBMSs promote the finding of data in large systems. RDBMSs can also be the source of data to generate reports and more importantly for this thesis analyse data. Therefore, the system development platform must utilise relational database management systems.

When defining the system architecture, it is key that the utilised platform is taken into consideration. It would be pointless to design an architecture that is outside the capabilities of the chosen platform. Software selection is outside the scope of this thesis as Company X has selected Microsoft PowerApps for the data collection platform. Microsoft describes PowerApps as a collection of apps that enables a development environment to build custom apps using services, and connectors within the platform. Custom apps developed in PowerApps can connect to stored data in underlying data platforms such as SharePoint.

PowerApps versatility makes it suitable for data collection. The app will be created in PowerApps canvas mode and then connected to Microsoft PowerBI to perform the analysis. The author of this thesis has taught himself Microsoft PowerApps over the last 6 months to ensure the architecture of the system can be designed around the PowerApps platform.

PowerApps was chosen for its low code feature which allows custom app development with no code features but does allow code to be used where more complex tasks need to be performed. PowerApps is a good fit to design a structured data collection system app because PowerApps:

- uses no code features for easy app creation.
- allows the use of code for more complex tasks.
- integrates easily with Microsoft PowerBI which can be utilised as an analysis tool.
- has a large support community.

- integrates easily with storage options already utilised at Company X such as Microsoft SharePoint.
- is cloud-based and can be utilised from any computer which can access the internet.
- utilises already established security controls such as user profile (access levels).
- utilises relational database management systems (SharePoint, Excel).

4.4 Conceptual Framework

The conceptual framework shown in figure 9 summarises the literature review section of this thesis.

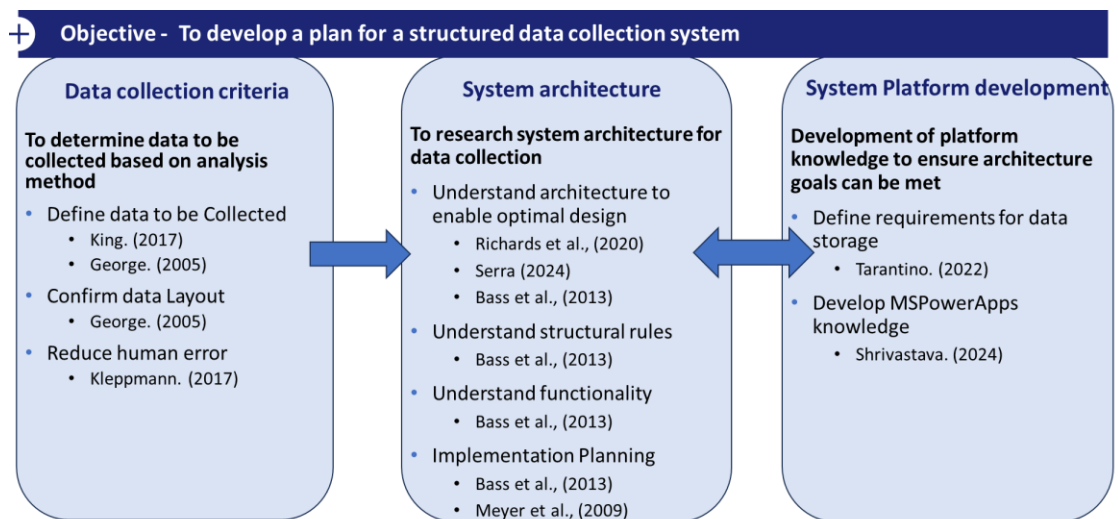


Figure 9 – Conceptual Framework

Figure 9 provides a summary of the key areas that need to be addressed during the creation of the structured data collection system plan. Figure 9 shows how each area of research defined by the current state analysis section is then addressed and which authors were selected for the research.

The findings in section 3 current state analysis and section 4 literature review will now be addressed in section 5 which is the creation of the initial plan for the structured data collection system.

5 Design System Plan

Section 5 is the initial structured data collection system plan creation step. It details the creation of the initial plan from workshop outcomes. The initial plan will be influenced by the requirements set out by the current state analysis and literature review in sections 3 and 4. To fully release the requirements of the current state analysis and literature review, the initial plan will be iterated by the author in section 6 where the final proposal is documented. Figure 10 below gives an overview of a five-step plan to create the structured data collection system plan. This five-step plan will be covered in sections 5 and 6 of this thesis but the numerical steps are for presentation purposes and not referred to in the thesis.

R = Responsible, A = Accountable, C = Consulted, I = Informed

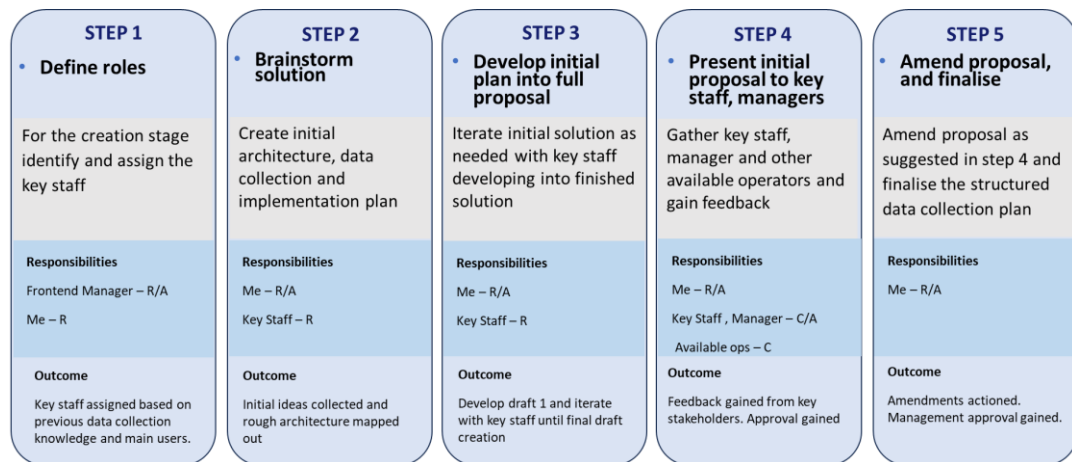


Figure 10 – Five-step plan for structured data collection system plan creation.

The five-step plan in figure 10 is used to present the structure of the creation phase. The five-step plan is not referred to in the thesis but was used for project management to present to the stakeholders involved. Step 1 will define the roles of the key staff who will help create the initial proposal; step 2 consists of a brainstorming session to gain initial ideas; step 3 develops the initial ideas into a proposal iterating with the key staff as needed; step 4 is presenting the proposal

to the key staff and managers; step 5 will be to finalise the proposal based on feedback from the presentation. The thesis association with the step names can be found in the future headings of the thesis.

5.1 Defining Roles

The Frontend Manager and the author appointed two people to aid with problem-solving and further discussions, operator 1 and operator 2. This allocation of resources through management will enable the chosen personnel to dedicate time while also fulfilling their annual targets set by management. Operators 1 and 2 will now be referred to as the key staff.

The key staff were chosen for their previous knowledge of data collection systems in previous employment and as the main users of the proposed structured data collection system. Creating the structured data collection system with the key staff will also aid the change management needed when the implementation of said system is performed.

The key staff will engage with the data collection 2 stage which will be outlined further in steps 2 and 3, they will also approve the initial plan proposal in step 4 along with the frontend Manager.

5.2 Brainstorming

5.2.1 Brainstorming System Architecture

To initiate data collection 2 (see figure 4 – Data Plan), a workshop was organised for the key staff and the thesis author. The workshop was face-to-face to enable better interaction between the participants and was semi-structured. The first part of the workshop was structured and consisted of the thesis author briefly presenting the findings from the current state analysis and literature research. The second unstructured part of the workshop was a brainstorming session to generate ideas for the three main requirement subjects

as detailed in figure 9 Conceptual Framework; to map a new structured data collection system architecture; consider data collection criteria; and utilising the system platform features.

The thesis author chaired the brainstorming session capturing ideas on a whiteboard and influencing the session with previous knowledge gained from the literature research. A photograph of the whiteboard at the end of this session can be seen in Appendix A. Figure 11 below shows the outcome of the workshop.

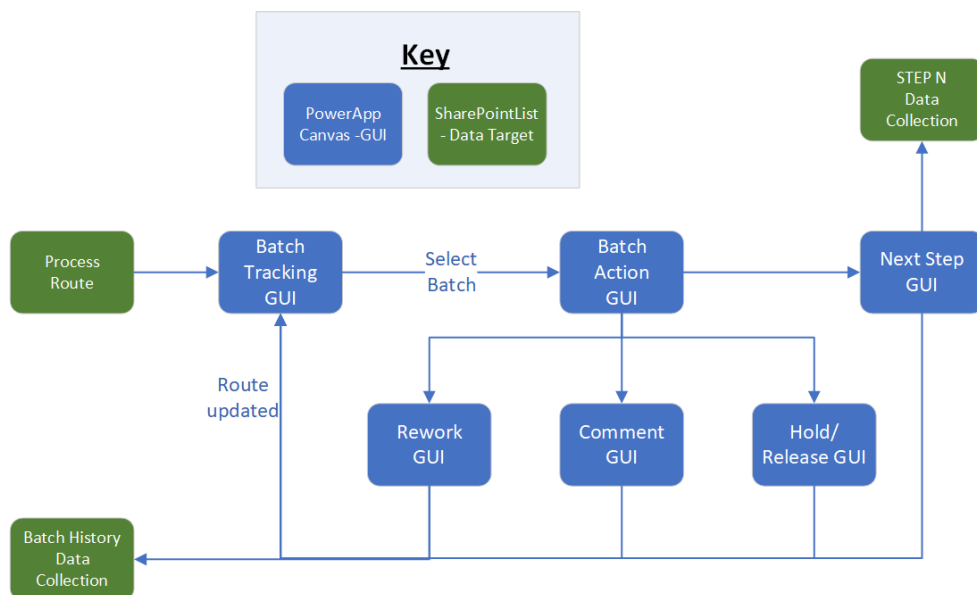


Figure 11 – Initial system architecture map from the brainstorming session.

Figure 11 shows the data collection system architecture from the workshop with graphical user interfaces (GUI) in the blue boxes. GUIs can display data stored in SharePoint lists which are a form of a relational database management system and are represented by the green boxes. Each GUI had their key features listed in the workshop, these features can be seen in Table 6 below.

GUI	Features
Batch Tracking	List of Batches
Batch Tracking	Scrap
Batch Tracking	New Batch Creation
Batch Tracking	Select Batch for Action
Batch Tracking	Batch History Display
Batch Action	Next Step
Batch Action	Rework
Batch Action	Comment
Batch Action	Hold/Release
Next Step	(Data Input unique to step)
Rework	Reposition Batch
Comment	Add comment to batch history
Hold/Release	Hold Batch - with comment
Hold/Release	Release batch - with comment

Table 6 – List of GUI features from the workshop

Table 6 lists the features each GUI owns. These features connect with the variables contained in the SharePoint lists and are updated when data is presented by a GUI. The variables for each SharePoint list identified in the workshop are listed in table 7 below.

SharePoint List	Variables
Step Data Collection	Timestamp
Step Data Collection	Equipment Id
Step Data Collection	Recipe
Step Data Collection	Step name
Step Data Collection	User Id (Operator)
Step Data Collection	Measurement data
Batch History	Timestamp
Batch History	Comments (Hold/Release/Comment)
Batch History	Rework Details
Batch History	Equipment Id
Batch History	User Id (Operator)
Batch History	Step Name
Process Route	List of route steps

Table 7 – List of SharePoint variables from the workshop

The variables seen in table 7 can be altered by the user interaction in a GUI. This interaction between the GUI and the SharePoint lists gives the ability for the data collection to be controlled.

Referring to the system architecture in figure 11 the step iteration workflow is shown below in figure 12.

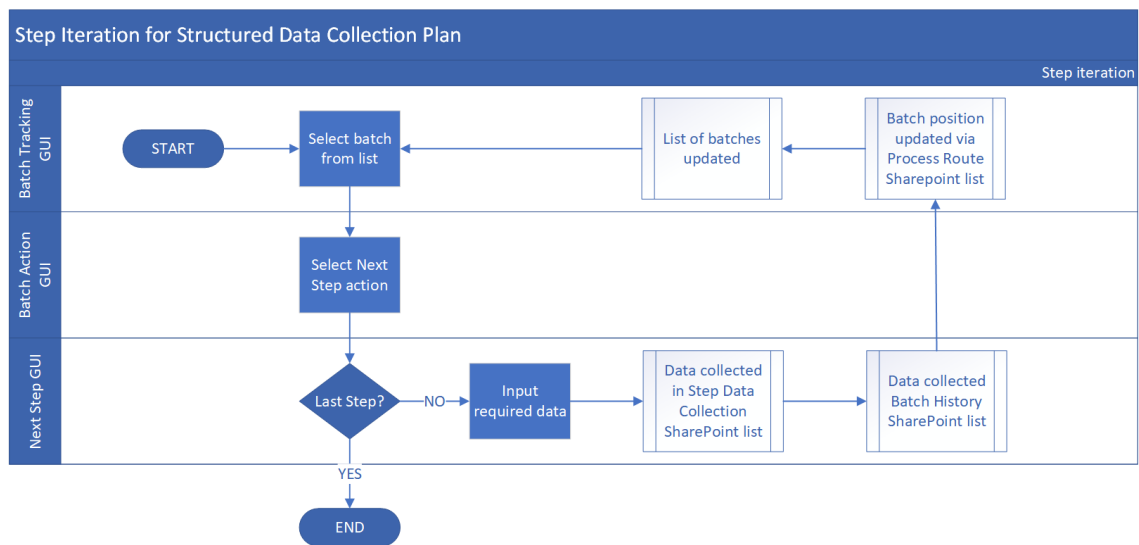


Figure 12 – Workflow for step iteration using architecture created during the workshop.

To aid the explanation for step iteration, figure 12 shows the workflow. The workflow starts with the Batch Tracking GUI where the batch is selected from the displayed list by the user. Next, the user selects the Next Step from the batch action GUI. If the batch is not at the end of its route, then the system displays the Next Step GUI where the user inputs the data required. The system then goes through a series of sub-processes showing where the data is stored, and which data is updated for the process route. This cycle is repeated until all the steps are completed. All steps are mandatory and therefore force the operator to input data improving data quality.

Maps of other GUI actions are not mapped out. The other GUIs are one-off actions for engineering tasks. The author does not detail their function here as

the current system architecture is incomplete as will be detailed in the section summary.

5.2.2 Brainstorming Data Collection Criteria and Human Error

Each step in the manufacturing process will have a unique data collection requirement and these requirements must be established through a data collection plan. The key staff agreed to utilise the data collection plan provided by George (2005) which formed part of the literature review section.

The key staff strongly indicated that restrictions should be applied to all SharePoint lists to stop accidental corruption, user accounts with different restrictions will be created to control access to SharePoint lists. The GUIs will only allow data input or system actions and the displayed data cannot be corrupted further improving the quality of data.

5.2.3 Brainstorming Implementation of System

Implementation of the structured data collection system was brainstormed during the workshop. The objective of the thesis is to create a plan for a structured data collection system and therefore should include direction for implementation.

The key staff agreed with a five-step implementation plan for post-thesis actions which is detailed below.

1. Creation of App – Using the data collection system plan created for this thesis to create the application in Microsoft PowerApps, this will include testing.
2. Demonstrate created application for approval – Gain approval from all key stakeholders.

3. Training – Train all staff who will utilise the application.
4. Implementation – Use the ‘Big Bang’ implementation method as section-by-section implementation is not an option.
5. Data analysis planning – Initiate the data analysis stage utilising Microsoft PowerBI.

5.2.4 Summary of Brainstorming Workshop

The brainstorming session was a successful first step to gaining initial information to start the creation of the structured data collection system plan. The key staff can't create a comprehensive architecture as this must be developed further with PowerApps structural knowledge and in general, will need more deliberating. Therefore, this section does not detail how the brainstorming workshop falls short of the literature review findings and only details the data captured during the workshop. The next section will show how the thesis author evolves the brainstorming ideas using the key staff to gain further information as required.

6 Final Proposal

To further develop the data collected to create an initial proposal during the brainstorming workshop the author will now use their experience and further knowledge gained in the literature review to create the final proposal. This creation process includes the key staff who will be asked for their opinion on certain steps. Communication with the key staff will be via any means such as email, messaging, or face-to-face. The data collected from the key staff during this period concerns only approval of the author's creation at intervals, only major input from the key staff will be documented if any. This section details the final proposal and not any iterations in between the brainstorming session and the final proposal.

6.1 System Architecture

The system architecture created by the brainstorm is inadequate and does not fulfil the functional requirement set out in the literature review. The author therefore further developed the architecture for a structured data collection system resulting in figure 13 below.

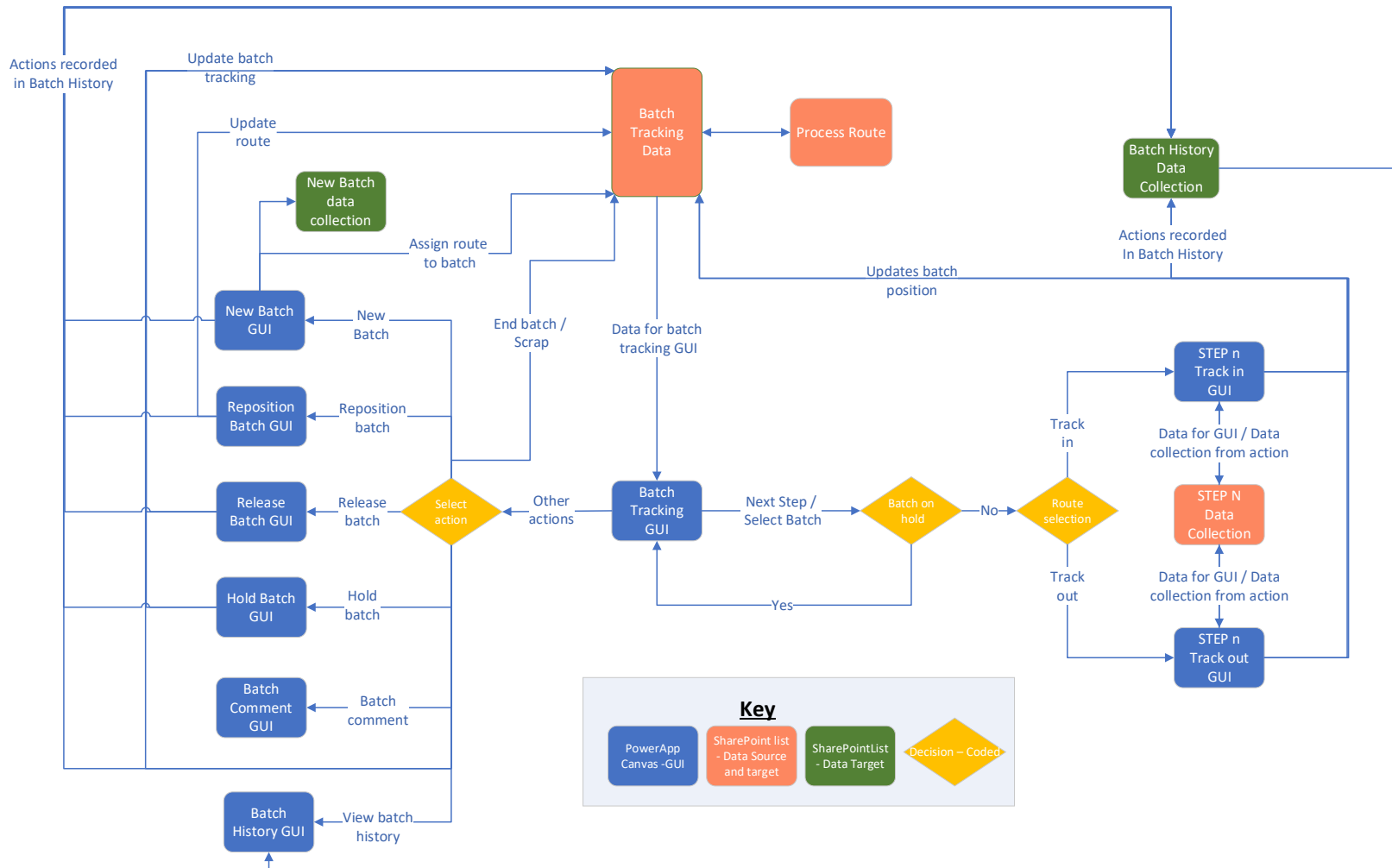


Figure 13 – Structured Data Collection System Architecture, Final Proposal

6.1.1 GUI Functionality Attribute Tables

Figure 13 defines the data architecture framework at a high level. Blue boxes indicate the use of a GUI which displays data which is pulled from available variables located in associated SharePoint lists. The GUIs can also require data input, in this case the GUI pulls the variable name from an associated SharePoint list and input boxes are displayed for the user.

Using PowerApp features these inputs can be forced meaning the user can progress the batch unless the data is inputted. Other restrictions on data input can be applied to further increase data quality by reducing human error such as using drop-down lists to limit the input to only a few options. To further explain GUI functionality table 8 and 9 below display the functional attributes of the Batch Tracking GUI and the Step Track In GUI.

Batch Tracking GUI			
Inputs Sources	Parameter	Data Type	Variables
Batch Tracking Data	Batch ID	Fixed	Fixed at creation
Batch Tracking Data	Wafer ID	Fixed	Fixed at creation
Batch Tracking Data	Slot No.	Fixed	Fixed at creation
Batch Tracking Data	Product	Fixed	Fixed at creation
Batch Tracking Data	WaferMark	Fixed	Fixed at creation
Batch Tracking Data	State	Auto updates after each step	Track In, Track Out
Batch Tracking Data	Step	Auto updates after each step	Displays name of step
Batch Tracking Data	OpCode	Auto updates after each step	Displays current Opcode
Batch Tracking Data	Assignment	Fixed	Fixed at creation
Batch Tracking Data	Box	Auto updates from track-out	User-defined at track-out
<i>The data above is shown for each active batch in a list format.</i>			
Output Buttons	Function		
Hold	Navigates to Hold GUI		
Release	Navigates to Release GUI		
Reposition	Navigates to Reposition GUI		
Comment	Navigates to Comment GUI		
End/Scrap Wafer	Navigates to End/Scrap Wafer GUI		
Next Step	Navigates to Track In or Track Out GUI dependent on stage. Available for each batch		
View History	Navigates to Batch History GUI		
Search Function	Searches batches within the Batch Tracking Data SharePoint list		
Access			
All users can use all functions			
Cannot edit list from GUI			

Table 8 – Batch Tracking GUI functional attributes

Step Track In GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target
Batch Tracking Data	Batch ID	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Wafer ID	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Slot No.	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Box	Auto updates from last track-out	User-defined at track-out	Data Collection Step
Batch Tracking Data	Product	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Step	Fixed	Fixed at creation	Data Collection Step and Batch History
Operator list	Operator	Drop down list (forced)	List of operators	Data Collection Step and Batch History
Data Collection Step	Recipe Name	Drop down list (forced)	List of recipes	Data Collection Step and Batch History
Data Collection Step	Equipment name	Drop down list (forced)	List of equipment	Data Collection Step and Batch History
Data Collection Step	Track in Comments	Text	Manual entry - Optional	Data Collection Step and Batch History
Batch Tracking Data	Multiple Batch Selection	Tick box (at least one batch)	Calculated - Batches at current step	Data Collection Step
Auto-generated by track In button	TrackIn TimeStamp	n/a	Current time	Data Collection Step and Batch History
Output Buttons		Function		
Copy Data	Copies data for reuse			
Paste Data	Pastes copied data for reuse			
Track In	Checks all entries are complete and sends data to targets			
Access				
All users can use all functions				
Cannot edit fixed data from GUI				

Table 9 – Step Track In GUI functional attributes

Table 8 and 9 are the functional attributes of the Batch Tracking GUI and the Step Track In GUI, the remaining GUIs have their functional attribute tables in Appendix B. Each table is in three separate parts; data functionality; Output Buttons; and Access. These are described below.

Data functionality – the first column is the input source, which is a reference to where the data is being obtained from. The second column is the parameter being used from that source and the third column displays the data type. The data type column has a colour code to indicate the risk of poor data entry, the key for this is below in figure 14.



Figure 14 – Traffic light system

In figure 14 'no risk' indicates that the data cannot be changed at this stage; 'controlled' indicates that manual input is needed but this is controlled using a drop-down list or other control method; 'manual entry' indicates typed input.

The fourth column describes the variable data and if the data is fixed, has further control limits, or offers a description of the data. The traffic light system in figure 14 is also used here to indicate further control parameters such as data input requirements or the importance of data collection. The fifth column, if present, shows the data target and/or use. The target is the SharePoint list which will be updated or populated with this data. The use information in column five is a description of how the data is used, which will be either searching for data or identifying the row in the target data for the data input.

Output Buttons – This is a list of buttons and their functionality. Buttons are used to execute commands so are used to send the required data to the target. Buttons will also be coded to check all data input boxes have been completed and are within any control limits defined. The user will not be able to proceed if

the data entry criteria are not met. The function column defines the associated GUI and together with the other sections provides the GUI explanation.

Access – This section of the functional attribute table details the access rights for each GUI. Some users will not be able to access all GUIs. Limitation of access will enable control of data collection, with more error-prone actions such as repositioning only available to experienced users with the correct engineering knowledge. The access section also states that fixed data cannot be changed from a GUI.

6.1.2 GUI Module Overview

The functionality of each GUI can now be seen with the provided functional attribute tables, however, to clarify the purpose of each GUI for the manufacturing processes, a brief explanation is below.

Batch Tracking GUI – Provides a list of active batches and key details of each batch to enable planning and execution of actions. This is the main GUI and will be shown when the application is loaded. See the functional attribute table in Appendix B for a full description.

Step N Track In GUI – Requests the track in data at the start of a manufacturing step such as recipe and equipment allocation including time stamp and sends the inputted data to the data targets. See the functional attribute table in Appendix B for a full description.

Step N Track Out GUI – Requests the track-out data at the end of a manufacturing step such as product measurement data, including time stamp and sends the inputted data to the data targets. See the functional attribute table in Appendix B for a full description.

New Batch GUI – Requests data such as batch ID and product which then populates the Batch Tracking Data SharePoint list. This GUI also requests

supplier information. See the functional attribute table in Appendix B for a full description.

Reposition GUI – Enables the user to reposition a batch in case a reprocess is needed or other engineering actions. See the functional attribute table in Appendix B for a full description.

Hold Batch GUI – Enables the user to stop the batch from progressing, used if a batch has an issue and shouldn't continue until rectified. Requires a comment stipulating why the batch is on hold. See the functional attribute table in Appendix B for a full description.

Release Batch GUI – Enables the user to release a batch from a previous hold action, used if the batch issue is resolved and the batch can continue on the manufacturing route. Requires a comment stipulating why the batch has been released. See the functional attribute table in Appendix B for a full description.

Batch Comment GUI – Enables the user to add comments at any step or stage which is recorded in batch history. See the functional attribute table in Appendix B for a full description.

Batch History GUI – Displays a selected batch's history. See the functional attribute table in Appendix B for a full description.

6.1.3 SharePoint Lists Overview

In the structured data collection system architecture in figure 13, SharePoint lists are used to store data and to provide data to GUIs for display. The SharePoint Lists are either green which indicates a data target where the data cannot be changed or pink which indicates the SharePoint list can be changed with GUI interaction. All SharePoint lists will have a column for each variable an example can be seen below in figure 15.

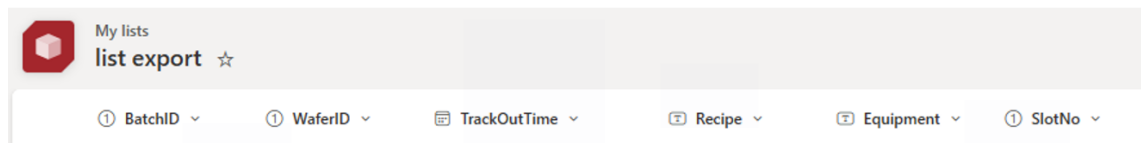


Figure 15 – Example of an unpopulated SharePoint list.

Access will not be granted to SharePoint lists for all users of the data collection system, instead, all the data is collected via the GUIs this includes a batch history for user reference. Data in the SharePoint lists will be referenced by Microsoft PowerBI for data analysis, but this is outside the scope of this thesis. Access to the SharePoint lists will be administrative only.

There are five SharePoint lists in the data collection system architecture final proposal; Batch Tracking Data; Process Route; Batch History Data Collection; Step N Data Collection; and New Batch Data Collection. These five SharePoint lists are described below. A list of variables for all the SharePoint lists can be found in Appendix C.

Batch Tracking Data – This SharePoint list records the current position of all the batches and is therefore a list of batches which is used to track batches through the multiple manufacturing steps. Historic data is not stored in the Batch Tracking Data SharePoint list only the status of batches, the manufacturing step is updated with interaction with the Process Route SharePoint list. The list of batches is displayed in the Batch Tracking GUI which will be the load-up screen for the application. There is only one instance of the Batch Tracking Data SharePoint list.

Process Route – This is a pre-determined SharePoint list which details the manufacturing steps, stage (Track In or Track Out) and the opcode which will be used for numerical reference. Each process route will have its own SharePoint list. The Batch Tracking Data SharePoint list can be updated by referencing the Process Route SharePoint list and performing numerical iteration on the opcode and thus finds the next step.

Batch History Data Collection – This SharePoint list records the history of the batch at each step recording key information at each stage, each batch will have its own SharePoint list. Batch history is vital when fault-finding manufacturing issues and provides traceability. The data collected at this step is common to all batches and steps.

Step N Data Collection – This SharePoint list is the data collected at each step with each step having its own SharePoint list. This is key data collection for statistical process control (SPC) which will be utilised in data analysis for process control. The individual step data is used to analyse that step only with a history of data from the batches processed through the step. Steps often contain measurement data which will be unique to each step, so each step data must have its data collection criteria defined. To define the criteria for each step the data collection plan (George, 2005) shown in figure 7 will be used.

New Batch Data Collection – This SharePoint list is populated every time a new batch is created with data from the New Batch GUI inputted by the user populating the New Batch Data Collection SharePoint list. This is a unique step and defines data such as batch ID, wafer ID, and product which will be fixed for all the manufacturing steps and define the manufacturing route for different products. Supplier information is also captured in the New Batch Data Collection SharePoint list so serves as a historic supplier data collection with a list of batches created. There is only one instance of the New Batch Data Collection.

6.1.4 Workflow Example

Supported by the GUI functionality attribute tables, GUI module overview, and the SharePoint lists overview it is now possible to fully understand the functional architecture displayed in figure 13. To further analyse and explain the structured data collection system detailed in figure 13, a workflow example is provided. The workflow example will only document the most common action, which is to track in and out of a manufacturing step.

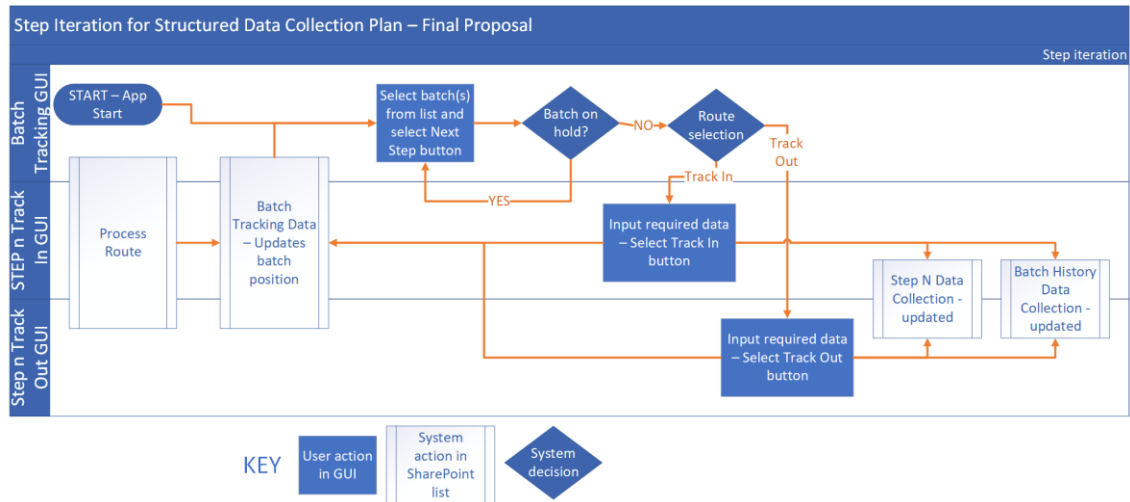


Figure 16 – Workflow of step iteration

The workflow of figure 16 emphasises the user and system actions for step iteration within the system architecture in figure 13. The list below describes this workflow, element by element, from the starting point of a batch (batch X) waiting for the track in action into the next step.

1. The app is loaded and will default to the Batch Tracking GUI which displays a list of batches within the manufacturing environment.
2. Batch X is selected by the user and the Next Step button selected.
3. The system checks to see if batch X is on hold. If the batch is on hold, the batch is not allowed to continue. If the batch is not on hold, the system proceeds to the next element.
4. The system uses the current state and step information provided to navigate to the next action for that batch, which is either track in or track out of the current manufacturing step. For this example, batch X is waiting for track-in.

5. The application now displays the Track In GUI, which shows the batch information provided by the connected SharePoint lists and also prompts the user to input data. The input data is specified by the variables in the Step n Data Collection and the Batch History SharePoint lists.
6. The user then inputs the required data and selects any additional batches to be tracked in and then selects the Track In button. The user cannot continue unless all data is entered. The user will now proceed to physically execute the current manufacturing step.
7. Step n Data Collection and the Batch History SharePoint list are now populated with the data. Batch Tracking data is also updated with the status changing from track in to track out.
8. Once the manufacturing process of batch X is completed, the user initiates the track-out action by selecting the batch from the list in the Batch Tracking GUI and selecting the Next Step button.
9. The system checks to see if the batch is on hold. If the batch is on hold, the batch is not allowed to continue. If the batch is not on hold, the system proceeds to the next element.
10. The system uses the current state and step information provided to navigate to the next action for that batch, which is either track in or track out of the current manufacturing step. Batch X is now waiting for track out.
11. The application now displays the Track Out GUI, which displays the batch information provided by the connected SharePoint lists and also prompts the user to input data. The input data is specified by the variables in the Step n Data Collection and the Batch History SharePoint lists.

12. The user then inputs the required data and selects any additional batches to be tracked out and then selects the Track Out button. The user cannot continue unless all data is entered. Batch X has now completed the manufacturing.
13. Step n Data Collection and the Batch History SharePoint list are now populated with the data. Batch Tracking data is also updated with the status changing from track out to track in. The step variable is also updated in the Batch Tracking Data, which iterates to the next step by interacting with the Process Route SharePoint list. Batch X is now waiting for track in at the next step.
14. The above process is repeated until all the steps have been completed and Batch X needs no further processing. No application function will exist to remove batch X from the application once all steps have been completed. Batch deletion will be performed manually by administrators, as each batch will be reviewed for quality purposes before removal, which is outside this thesis's scope.

6.1.5 Data Storage and Management

The created application will be stored on a preexisting cloud server for company X. The PowerApp platform and SharePoint lists are both part of the Microsoft environment and are designed to be compatible with such architecture as created for the structured data collection system.

Once the functional structured data collection system application is released, it will enable the efficient and effective handling of data. This will ensure good quality data stored in a consistent format and will enable effective data analysis software to be implemented. The collection for the requirements of each step will be gained by using the data collection plan as detailed in figure 7 provided by George (2005).

6.2 Data Collection and Management

A key part of the final proposal is how data is collected in the system. The subsections will further explore how data collection is handled with the structured data collection system final proposal.

6.2.1 Collection of Step Requirements for Data

All steps will have many common attributes however some of the individual step requirements will be unique. To gather this unique step information the data will be gained by using the data collection plan as detailed in figure 7 provided by George (2005). This format will ensure data commonly used for SPC analysis is correctly recorded in the data collection system for a data analysis to be implemented after thesis completion.

Detailed analysis of manufacturing steps can only be made if all the data is entered at each occurrence and in the same format. The proposed system forces this data input by the user who cannot proceed to the next step without satisfying the system input requirements.

6.2.2 Reuse of Data

The reuse of data decouples the user from many data inputs. The sharing of the data from one SharePoint list to another via the GUI interface minimises the user input thus reducing the opportunities for error.

By using the GUI functionality attribute tables, the reuse of data can be quantified for the example in figure 16 for the step iteration process. The number of instances when individual data was displayed in a GUI from a SharePoint list is 32. The number of times data was transferred from one SharePoint list to another via the GUI is 15. The number of data inputs needed by the user to populate part of the SharePoint list is 10. Therefore only 10 opportunities for data error by the user exist and all but 2 of these user inputs

have controls such as dropdown lists or numerical limits to further reduce error. The 2 manual inputs without system control are comment inputs, which is optional and not forced for the step iteration process.

6.2.3 Restrictions on Manual Data Input

User input will be required for the system and errors may occur in these instances. To reduce the risk of error restrictions on the input have been applied, these restrictions can be seen in the GUI functional attributes tables, in the data type column, see Appendix B. As previously mentioned in figure 14 a traffic light system is employed to highlight the risk of data error via user input. Green is no risk; amber has data input restrictions; and red is manual input. A list of these amber restrictions is detailed below.

- Drop-down list – Where variables are limited, drop-down lists will be employed so users do not need to manually type the variable into the application GUI.
- Control limits – Numerical inputs will have an upper and lower limit as the input should be in a certain range. This reduces the common error of one too many digits or one too few digits during user input. When failure occurs with real data, this will signal to the user that a manufacturing step processing error has occurred.
- Tick boxes – Used to select from a limited number of options by checking the box required. This action is used when multiple choices may be selected (multiple batch selection).

Red manual input is limited to comment entries and signals a user entry with no limitations. Comments are not required for every GUI input and are the only variable which isn't forced in the step iteration process, see figure 16.

Comments are forced for issues such as repositioning a batch, so the engineer must justify their decision. Comments are not used in SPC charting such as

shew charts but will be used when reviewing batch histories to gain insight into non-standard engineering actions. Data analysis will not be affected by the comments input and there is no way a system can check if the comment made by an engineer is adequate. Adequate engineering comments can only be assessed and actioned by system governance actioning individual cases with discussion and training when needed.

6.2.4 Error Recovery

Although the threat to the quality of data is greatly reduced by reuse and restrictions it is still possible to have data errors due to human input. Recovery of such errors is paramount for future analysis. Error recovery will be dealt with by the user re-entering the data and informing the administrator the data was incorrect so the previous input can be removed. Large quantities of data exist in the SharePoint lists and can be corrupted accidentally by the user therefore access to the lists is limited to administration only. Once the correct data is entered by the user the user can proceed with the next step and will not have to wait for the administrator to remove the previous entry.

What happens if the user doesn't spot their error? Key SPC data should flag such events in the analysis stage but other inputs such as equipment ID may go unnoticed. Unfortunately, where user input is required, there is always room for error. This type of error can be handled by reducing the number of opportunities available for error as this thesis previously details, and effective training and management.

6.2.5 Monitoring, Management and Training

Monitoring the proposed structured data collection system will take three forms.

- Output of the data analysis – Although outside the scope of this thesis, once the data analysis system is implemented, the data from each step which contains SPC attributes will be displayed in chart form. This chart

is used to assess the batch's suitability to continue to the next step of the manufacturing route. Therefore, the assessment of SPC data is monitoring the system and where failure occurs, the user will fault find whether the cause is the data collection system or the associated manufacturing step.

- Structured data collection system administrator – Batches will be reviewed on completion for correct processing which in turn checks the system executed its function correctly during the process route. Immediately after implementation, the administrator will be performing daily checks to ensure no issues are found, a daily check should not be needed as confidence is gained in the system. Once confidence is gained a quarterly meeting should be held to review system functionality and suggest improvement although these could also be ad-hoc meetings.
- User stoppages – Monitoring the structured data collection system will also be enforced by the users of the system. Users can not progress the batch if the system does not perform correctly and will need to contact the administrator. The use of the system is so frequent by the user that issues will likely be found by the user first.

The main administrator for the data collection system will effectively be the manager. The administrator will have the knowledge and access to manipulate the system to fault find, evolve, and determine access rights. The administrator would also be responsible for user training initially. Due to the simplicity of use of the proposed data collection system, user training would soon be outsourced to experienced users. The administrator would need to train a second administrator as there is a need to have at least two people able to problem-solve, in case one person leaves or is on holiday.

6.3 Stakeholder and Management Final Approval

To gain approval for the structured data collection system plan final proposal a presentation was delivered to the key stakeholders consisting of:

- Key staff (operators 1 and 2)
- Front-end Manager

The presentation slides can be found in Appendix D and serves as data collection 3. The feedback from the presentation was positive with all participants actively engaging in discussion indicating that change management will not be an obstacle for the project going forward.

Minor improvement suggestions were made during key stakeholder discussions. All suggestions concerned the project going forward such as the development of system specifics (coding), which is outside the scope of this thesis and does not influence the architecture. No changes to the final proposal were made due to the stakeholder and management final approval presentation.

7 Discussions and Conclusions

Section 7 of the thesis gives an executive summary of the thesis providing an overview of the steps taken to completion and outcomes achieved. A five-step implementation plan is then provided to drive the project beyond the thesis to the creation of the data analysis platform. The final part of section 7 provides a critical analysis of the thesis to give evidence of success and also any improvements which can be reflected.

7.1 Executive Summary

The objective of this thesis is to develop a plan for a structured data collection system for the semiconductor manufacturing site at Company X. The data collection system will collect data from each manufacturing step; record engineering interactions; record batch histories; track batches during the semiconductor fabrication process; and enable engineering ad-hoc actions. Ultimately the system will be connected to a data analysis platform so data is automatically analysed after each step and can also be used for other data-related improvements.

Using an applied research approach a research design plan is created to direct the thesis structure. This design plan maps four key stages of the thesis; current state analysis; literature review; design of the structured data collection system plan; and validation of the structured data collection system plan by the stakeholders.

The current state analysis required an outcome which would identify the system stakeholder's requirements by analysing the current data collection system. The analysis showed that the current system was inadequate, and a full redesign of the data collection system is required. Stakeholder requirements for the new system are noted from the current state analysis to aid the direction of the literature review. The current state analysis also showed a lack of company

knowledge of the importance of quality data and routine data analysis in a manufacturing environment.

Data collection, system architecture, and platform development are identified as the key literature review topics by the current state analysis stage. The data collection research investigates data required by the system and methods of collecting the variables needed for the system architecture. System architecture research is performed to ensure a functional modular system creation with quality attributes. System architecture research finds the need for a system which can be used to communicate with stakeholders, plan change, and most importantly implement the design phase after thesis completion. Company X chose the Microsoft PowerApps software for the system creation. The author of the thesis researched PowerApps to ensure the architecture can be realised with PowerApps and use its data-controlling features.

With key stakeholders, a brainstorming session is held to develop an initial proposal for the architecture and data collection plan. The initial proposal identifies the use of PowerApps graphical user interfaces and SharePoint lists to interact to create a well-defined modular system architecture for the structured data collection system. The brainstorming session also identified that data collection for the different manufacturing steps is a simple but vital step.

Further development of the initial proposal is now performed by the author who uses their prior experience and further knowledge gained in the literature review to create the final proposal. The resulting structured data collection system plan is a functional modular architecture (See figure 13, page 39) which can be applied to the PowerApps platform. The final proposal details how the reuse of data is used to enforce the quality of data and where manual input is required how PowerApps features can restrict the likelihood of user error. The final proposal details how the architecture will function in Company X's current cloud environment and defines all the system's modular features and their

interactions. All stakeholders approved the plan during a presentation of the system plan.

This thesis successfully creates the architecture for a structured data collection system which can be utilised in Company X's semiconductor manufacturing environment. The next step after the thesis will be to design and implement the system. Once implemented SharePoint lists will be populated automatically during manufacturing operations creating powerful historical data, which can be analysed automatically by data analysis tools such as Microsoft PowerBI. The analysis of this data can drive improvement in the manufacturing environment by reducing waste, improving yield, project assignment, in-line process control, planning, and contributing towards quality management. Structured data systems can also be used for preventative maintenance analysis and could also utilise artificial intelligence to reduce engineering workload.

Beyond the implementation of the structured data collection and analysis system, the author must ensure that all engineers engaged with manufacturing data analysis know the value of the data. Data should be collected in a structured format to ensure data quality, enabling automatic analysis immediately after generation, data should always be available for further analysis. Manufacturing personnel should be focused on data for continued product quality and improvement, driving yield improvement and increasing output to outperform their competitors.

7.2 Practical Next Step Recommendations

The topic of implementation is featured in the literature review and initial proposal and is further presented in this section. A five-step implementation plan is outlined in figure 17 below.

R = Responsible, A = Accountable, C = Consulted, I = Informed

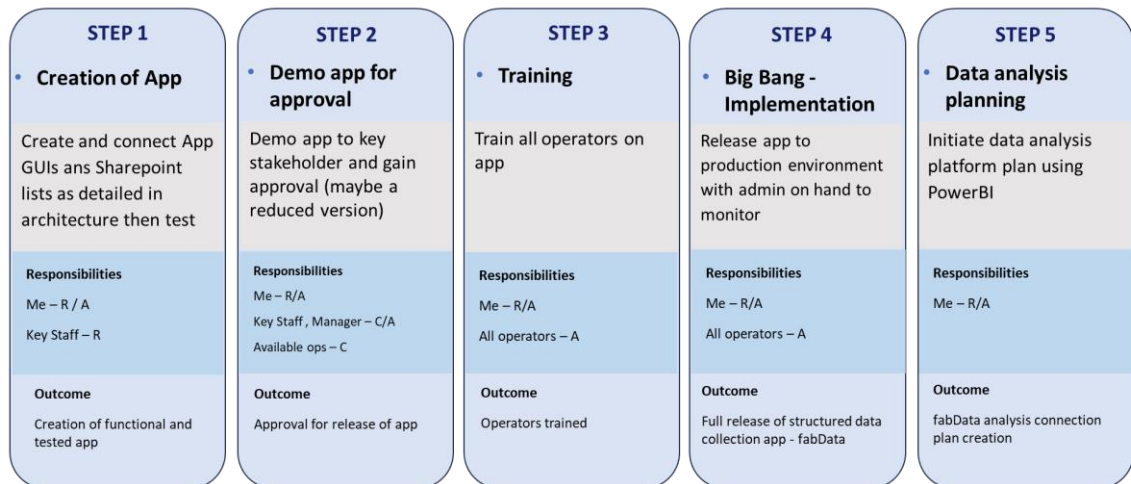


Figure 17 – Five-step implementation plan

Step 1 of figure 17 is to create the app which involves coding the PowerApp, connecting it with SharePoint lists, collecting the data needed for each manufacturing step creation, and testing.

Step 2 is to demo the app to key stakeholders to ensure it functions as they expected. If all functional aspects of this thesis are achieved during creation, then no resistance from stakeholders is expected at the approval step. No resistance is expected due to the previous change management steps during this thesis such as stakeholder interaction in creation, stakeholder requirement gathering and fulfillment, and approval of the architecture plan.

Step 3 is to ensure training for users of the created structured data collection system is provided. Full understanding will be aided by the architecture diagram of the system created in this thesis (figure 13). Further training is to be provided on the importance of data analysis to stress its analytical use. Administrator training will also begin at step 3 for a second administrator, but the focus will be on user training.

Step 4 is the implementation of the structured data collection system. The 'Big Bang' method of introduction detailed in the literature research section will be utilised. Due to the system needing a full manufacturing route to be functional, the system will be implemented to the whole manufacturing route at the same time. The manufacturing site is run during daylight hours so administrators can be on hand to troubleshoot any initial problems, if any.

Step 5 is the creation of the data analysis platform. Connection to Microsoft PowerBI will enable the data collected in the structured data collection system to be analysed. The analysis of this data can drive improvement in the manufacturing environment by reducing waste, improving yield, project assignment, in-line process control, planning, and contributing towards quality management. The creation plan of the data analysis platform should be planned after the creation of the structured data collection system to aid cohesion.

Beyond step 5 the author must ensure that all engineers engaged with manufacturing data analysis know the value of the data. Data should be collected in a structured format to ensure data quality and automatically analysed immediately after generation and always be available for further analysis. Manufacturing personnel should be focused on data for continued product quality and improvement, driving yield improvement and increasing output to outperform their competitors.

7.3 Self-Evaluation of Thesis Project Credibility

The structured data collection system plan has been created and accepted by the stakeholders, the stakeholders are engaged and positive towards the next steps beyond this thesis. I conclude this thesis to be successful, as not only has the objective of the thesis been fulfilled but change management aspects have ensured the continuation and momentum of the project beyond this thesis.

The logical format provided by the research design plan and data collection stages gave the thesis structure, enabling the author to approach the solution in

a logical and productive manner. Engagement with stakeholders at the three data collection stages ensured that not only the author is pushing to introduce the structured data collection system, but so are the stakeholders.

Data collection stages also ensured stakeholders were part of the creation of the structured data collection system plan. This further interaction provides a deep understanding of the project to the key users of the system. Evidence of stakeholder interaction can be found in Appendix A and D. However, the data captured by informal conversations where some key decisions were made was not captured in the thesis and could be a point for improvement.

Capture of stakeholder input is also provided in the current state analysis. The current state analysis offered little value to the author as their previous knowledge covered the requirements gained for the system at this stage of the thesis. However, the current state analysis did prove valuable for change management purposes, explaining to all stakeholders the benefits of a structured data analysis system and connecting data analysis. In hindsight, the author could have excluded the current state analysis or reduced its content and performed the change management as a separate action.

The system was validated by showing the amount of data gained without user input during the manufacturing process route, this can be referenced in figure 16 and supporting text in the reuse of data section. Where user interaction in the structured data collection system is necessary, the thesis clearly shows the restriction on the data input which reduces error and improves data quality. The author believes the only way to further reduce user interaction with the system would be to connect the manufacturing tools to the system, this automation is not possible at Company X.

Architectural functionality is validated by realising the modular design which is supported by the GUI Functional Attribute Tables and variable tables in Appendix B and C. The architecture and data aspects of the literature review can be seen in the final proposal. The final proposal also frequently references

the features in the PowerApps software and supporting SharePoint lists, showing how the software can support the architecture and data quality aspects of the thesis.

7.4 Closing Words

After gaining over fifteen years of experience in semiconductor process and manufacturing engineering, the author would like to thank every individual who has developed my skills or actively engaged me in problem-solving. I would also like to thank the instructors on the Industrial Management Masters course at Metropolia, whose knowledge has given me a different approach to management and business systems.

I would also like to acknowledge Company X, who have supported me with the thesis creation and continue to support me to progress the project beyond the thesis. Special thanks go to my family, especially Teina Ryyänen who always supports me and has certainly performed most of the household chores while the author creates this thesis.

References

Bass L, Clements P, Kazman R. 2003. Software Architecture in Practice, Second Edition. Addison-Wesley Professional.

George M, Maxey J, Rowlands D, Upton M. 2005. The Lean Six Sigma Pocket Toolbook: A Quick Reference Guide to Nearly 100 Tools for Improving Quality and Speed. McGraw-Hill Education – Europe.

Kananen J. 2013. Design research (applied action research) as thesis research: A practical guide for thesis research. Jyväskylä: Jyväskylän ammattikorkeakoulu.

King M. 2017. Statistics for Process Control Engineers. Wiley.

Kleppmann M. 2017. Designing Data-Intensive Applications. O'Reilly Media, Inc.

Kothari C R. 2004. Research Methodology : Methods and Techniques, New Age International Ltd. ProQuest Ebook Central

Abbott M L, McKinney J. 2012. Understanding and applying research design. Wiley User Research.

Microsoft. 2023. What is PowerApps? Available at: <https://learn.microsoft.com/en-us/power-apps/powerapps-overview> (Accessed: March 2024)

Meyer H, Fuchs F, Thiel K. 2009. Manufacturing Execution Systems Optimal Design, Planning, and Deployment. McGraw-Hill.

Richards M, Ford N. 2020. Fundamentals of Software Architecture. O'Reilly Media, Inc.

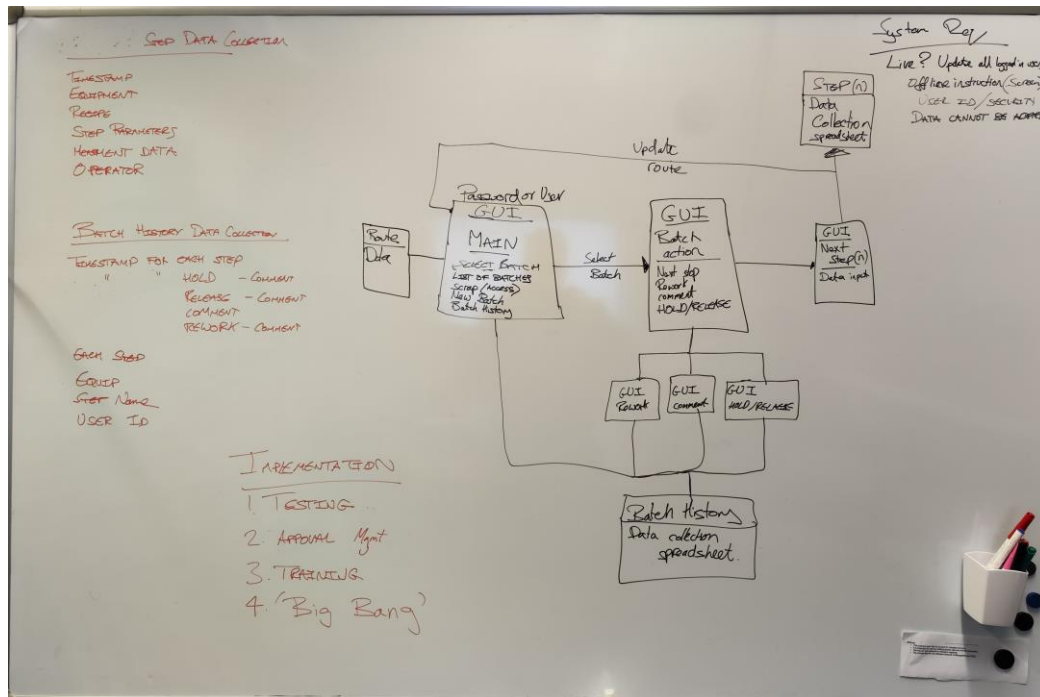
Serra J. 2024. Deciphering Data Architectures. O'Reilly Media, Inc.

Shewhart W A. 1939. Statistical Method from the Viewpoint of Quality Control.
Dover Publications Inc.

Shrivastava A. 2024. Learning Microsoft Power Apps. O'Reilly Media, Inc.

Tarantino A. 2022 . Smart Manufacturing. Wiley Innovation.

Appendix A – Initial Brainstorming Session



Appendix B – GUI Functional Attribute Tables

Batch Tracking GUI			
Inputs Sources	Parameter	Data Type	Variables
Batch Tracking Data	Batch ID	Fixed	Fixed at creation
Batch Tracking Data	Wafer ID	Fixed	Fixed at creation
Batch Tracking Data	Slot No.	Fixed	Fixed at creation
Batch Tracking Data	Product	Fixed	Fixed at creation
Batch Tracking Data	WaferMark	Fixed	Fixed at creation
Batch Tracking Data	State	Auto updates after each step	Track In, Track Out
Batch Tracking Data	Step	Auto updates after each step	Displays name of step
Batch Tracking Data	OpCode	Auto updates after each step	Displays current Opcode
Batch Tracking Data	Assignment	Fixed	Fixed at creation
Batch Tracking Data	Box	Auto updates from track-out	User-defined at track-out

<i>The data above is shown for each active batch in a list format.</i>	
Output Buttons	Function
Hold	Navigates to Hold GUI
Release	Navigates to Release GUI
Reposition	Navigates to Reposition GUI
Comment	Navigates to Comment GUI
End/Scrap Wafer	Navigates to End/Scrap Wafer GUI
Next Step	Navigates to Track In or Track Out GUI dependent on stage. Available for each batch
View History	Navigates to Batch History GUI
Search Function	Searches batches within the Batch Tracking Data SharePoint list
Access	
All users can use all functions	
Cannot edit list from GUI	

Step Track In GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target and/or Use
Batch Tracking Data	Batch ID	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Wafer ID	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Slot No.	Fixed	Fixed at creation	Data Collection Step
Batch Tracking Data	Box	Auto updates from last track-out	User-defined at track-out	Data Collection Step
Batch Tracking Data	Product	Fixed	Fixed at creation	Data Collection Step

Batch Tracking Data	Step	Fixed	Fixed at creation	Data Collection Step and Batch History
Operator list	Operator	Drop down list (forced)	List of operators	Data Collection Step and Batch History
Data Collection Step	Recipe Name	Drop down list (forced)	List of recipes	Data Collection Step and Batch History
Data Collection Step	Equipment name	Drop down list (forced)	List of equipment	Data Collection Step and Batch History
Data Collection Step	Track in Comments	Text	Manual entry - Optional	Data Collection Step and Batch History
Batch Tracking Data	Multiple Batch Selection	Tick box (at least one batch)	Calculated - Batches at the current step	Data Collection Step
Auto-generated by track In button	TrackIn TimeStamp	n/a	Current time	Data Collection Step and Batch History
Output Buttons				
	Function			
Copy Data	Copies data for reuse			
Paste Data	Pastes copied data for reuse			
Track In	Check all entries are complete and sends data to targets			
Access				
All users can use all functions				
Cannot edit fixed data from GUI				

Step Track Out GUI				
Inputs Sources	Parameter	Data Type	Variables	Target or use
Batch Tracking Data	Batch ID	Fixed	Fixed at creation	Data Collection Step searching
Batch Tracking Data	Wafer ID	Fixed	Fixed at creation	Data Collection Step searching

Batch Tracking Data	Slot No.	Integer	Manual entry with limits	Batch Tracking Data
Batch Tracking Data	Box	Integer	Manual entry with limits	Batch Tracking Data
Batch Tracking Data	Product	Fixed	Fixed at creation	Batch Tracking Data
Batch Tracking Data	Step	Fixed	Fixed at creation	Data Collection Step and Batch History
Data Collection Step	Measurement data (multiple inputs dependent on step)	Integer	Manual entry with limits	Data Collection Step
Auto-generated by track Out button	TrackOut TimeStamp	n/a	Current time	Data Collection Step and Batch History
Coded into app	Track Out Comments	Text	Manual entry - Optional	Data Collection Step
Operator list	Operator	Drop down list (forced)	List of operators	Data Collection Step and Batch History
Output Buttons				
Copy Data	Copies data for reuse			
Paste Data	Pastes copied data for reuse			
Track Out	Check all entries are complete and sends data to targets			
Access				
All users can use all functions				
Cannot edit fixed data from GUI				

New Batch GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target or use
Batch Tracking Data	Batch ID	Integer	Manual entry with limits	Batch Tracking Data and New Batch Data collection
Batch Tracking Data	Wafer ID	Integer	Manual entry with limits	Batch Tracking Data and New Batch Data collection
Batch Tracking Data	Slot No.	Integer	Manual entry with limits	Batch Tracking Data and New Batch Data collection
Batch Tracking Data	Box	Integer	Manual entry with limits	Batch Tracking Data and New Batch Data collection
Batch Tracking Data	Assignment	Drop down list (forced)		Batch Tracking Data and New Batch Data collection
Batch Tracking Data	Product	Drop down list (forced)	Fixed at creation	Batch Tracking Data and New Batch Data collection
New Batch Data Collection	Vendor Box ID	Integer	No control	New Batch Data Collection
New Batch Data Collection	Slot in vendor box	Integer	No control	New Batch Data Collection
New Batch Data Collection	Vendor product code	Integer	No control	New Batch Data Collection
New Batch Data Collection	Wafer number	Integer	No control	New Batch Data Collection

Auto-generated by track Out button	Creation TimeStamp	n/a	Current time	Data Collection Step, Batch History and New Batch Data collection
Operator list	Operator	Drop down list (forced)	List of operators	Data Collection Step, Batch History and New Batch Data collection
Output Buttons				
Function				
Add New Batch	Creates new batch in Batch Data Tracking, save input data to New Batch data collection and records action in Batch History collection.			
Access				
Limited users can create batches				
Cannot edit fixed data from GUI				

Reposition GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target or use
	Batch ID	Integer	Manual entry with limits	Identifies target batch
	Wafer ID	Integer	Manual entry with limits	Identifies target wafer
	New OpCode	Integer	Manual entry with limits	Opcode identifies the new required batch/wafer position
	Reposition comment	Text	Forced entry	Data Collection Step and Batch History
Operator list	Operator	Drop down list (forced)	List of operators	Data Collection Step and Batch History

Output Buttons	Function
Reposition	Repositions to input value of OpCode step via Batch Tracking Data and Process Route
Access	
Limited users can reposition batches	
Cannot edit fixed data from GUI	

Hold Batch GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target or use
	Batch ID	Integer	Manual entry with limits	Identifies target batch
	Wafer ID	Integer	Manual entry with limits	Identifies target wafer
	Hold comment	Text	Forced entry	Batch Tracking Data and Batch History
Operator list	Operator	Drop down list (forced)	List of operators	Batch Tracking Data and Batch History
Output Buttons	Function			
Hold	Stops batch from progressing further until release and displays comment for the reason why in history			
Access				
All users can hold batches				
Cannot edit fixed data from GUI				

Release Batch GUI

Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target or use
	Batch ID	Integer	Manual entry with limits	Identifies target batch
	Wafer ID	Integer	Manual entry with limits	Identifies target wafer
	Release comment	Text	Forced entry	Batch Tracking Data and Batch History
Operator list	Operator	Drop down list (forced)	List of operators	Batch Tracking Data and Batch History
Output Buttons				
	Function			
Hold	Allows batch to continue from hold position with a suitable comment			
Access				
Limited users can release batches				
Cannot edit fixed data from GUI				

Batch Comment GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target or use
	Batch ID	Integer	Manual entry with limits	Identifies target batch
	Wafer ID	Integer	Manual entry with limits	Identifies target wafer
	Comment	Text	Forced entry	Batch History
Operator list	Operator	Drop down list (forced)	List of operators	Batch History

Output Buttons	Function
Hold	Comment added to batch/wafer history
Access	
All users can comment on batches	
Cannot edit fixed data from GUI	

Batch History GUI				
Inputs Sources for GUI Display	Parameter	Data Type	Variables	Target or use
Batch History	Batch ID	Fixed		Display only
Batch History	Wafer ID	Fixed		Display only
Batch History	TimeStamps (Various actions)	Fixed		Display only
Batch History	Stage	Fixed		Display only
Batch History	Step	Fixed		Display only
Batch History	Comments (Various actions)	Fixed		Display only
Batch History	Reposition data	Fixed		Display only
Batch History	Hold data	Fixed		Display only
Batch History	Release data	Fixed		Display only
Batch History	Operator	Fixed		Display only
Output Buttons				
Function				
N/A				
Access				

All users can view the history
Cannot edit fixed data from GUI

Appendix C – SharePoint Lists Variable Tables

BatchTrack - Columns
Wafer ID
Batch ID
Slot No
Product
OpCode
Assignment
Step Name
Box
State
WAFERBATCHID
Hold Comments

Step Data Collection - Columns	
TrackInTime	
TrackOutTime	
Recipe	
Equipment	
BatchID	
WaferID	
SlotNo	
ProductID	
TrackInComments	
TrackOutComments	
ProcessCount	Coded
Measurement data	Repeated for each measurement point

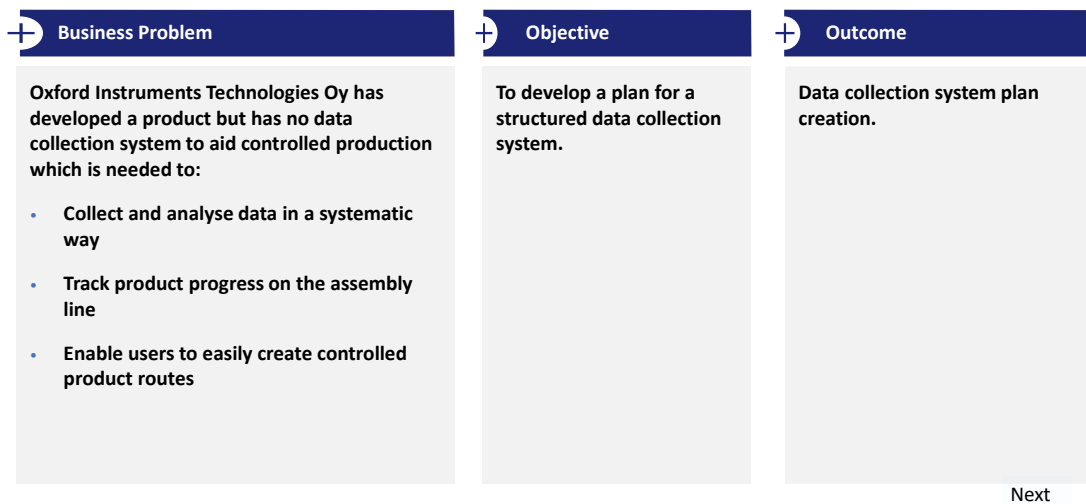
Process Route - Columns	
Step	For each step in process order
Stage	
OpCode	

Batch History - Columns	
TrackInTime	Relevant to operation
TrackOutTime	
Stage	
Step	
Comments	
Reposition data	
Release data	
Hold data	

New Batch Data Collection - Columns
Vendor product ID
Vendor Box ID
Batch ID
WaferID
Product
Assignment
Timestamp

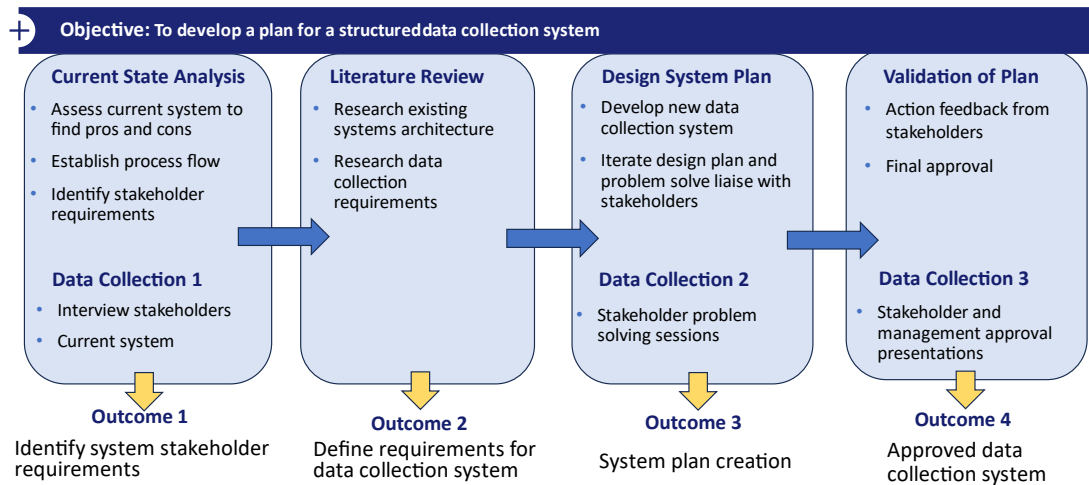
Appendix D – Final Proposal Presentation

Gate 1



1

Gate 2 – Research Design



Previous

Next

1

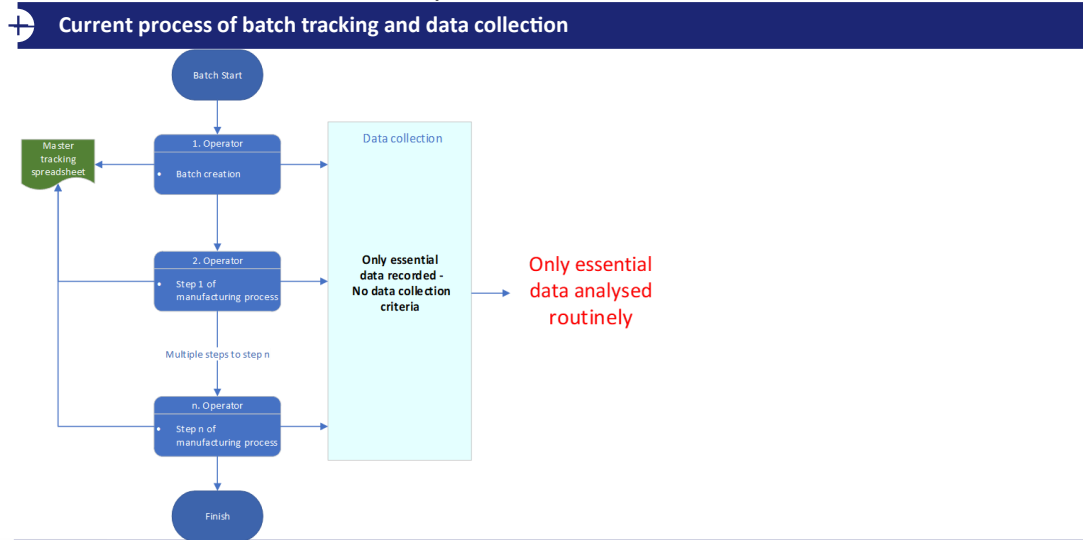
Gate 2 – Data Plan

+ Data Collection 1 – Initial evaluation			
Content	Source	Timing	Outcome
Evaluation of current system pros and cons	Internal system and documents	January 2024 (some collection is from 2023)	List of current system pros and cons
Stakeholder requirements	System user stakeholder interview (5 people)	January 2024 (some collection is from 2023)	List of stakeholder requirements
+ Data Collection 2 – Teamwork to find solution			
Content	Source	Timing	Outcome
Iterate through different possibilities, problem solving to find best solution	System stakeholder interviews and other communication	March 2024	Best solution realised Data collection system plan ready to be finalised
+ Data Collection 3 – Final Plan Approval			
Content	Source	Timing	Outcome
Plan presentation and approval	System stakeholders and Management presentations	April 2024	Plan approved

Previous

Next 2

Gate 3 – Current Process Map



Previous

Next 4

Gate 3 – Current Process

- Weaknesses	+ Strengths
<ul style="list-style-type: none"> • Human error corrupting data • No set data collection criteria • No designated data collection spreadsheet (no historic data) for many steps • No routine data analysis after each step • Does not force the operator to input data or move to next step • Data can be changed at any time by anyone • Data is often missing with no accountability • Minimal data collected 	<ul style="list-style-type: none"> • Tracking spreadsheet does track batches effectively if updated • No/little knowledge of system needed

Previous

Next 5

Gate 3 – Current State Analysis Findings

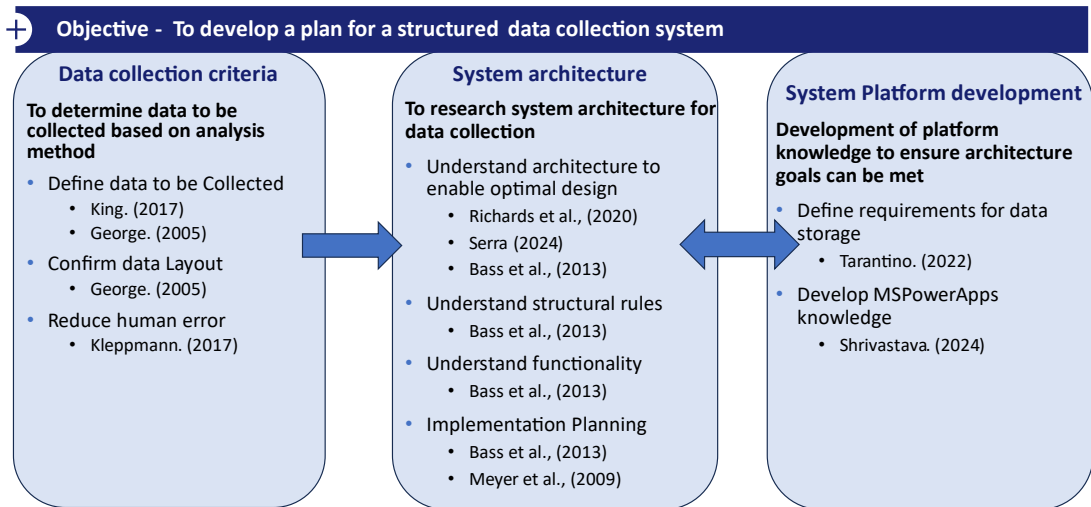
+ Summary	+ Focus for Redesign
<ul style="list-style-type: none"> • No to little knowledge of how effective a functional structured data collection and analysis system is. • Full redesign needed 	<ul style="list-style-type: none"> • Data collection criteria • Data, batch tracking and storage interaction (system architecture) • System platform development – Minor focus



Previous

Next 6

Gate 4 – Conceptual Framework

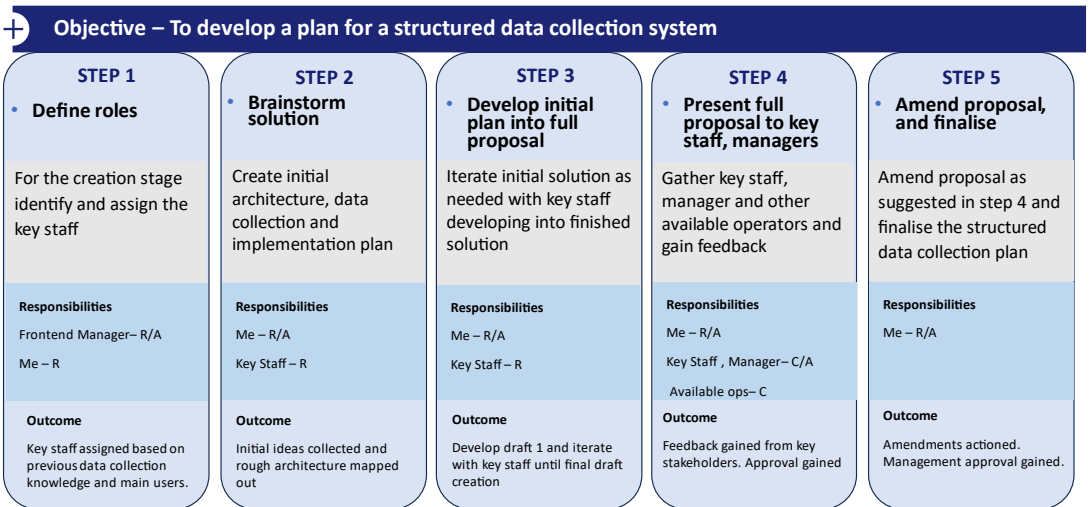


Previous

Next 7

Path to Plan Approval

R = Responsible, A = Accountable, C = Consulted, I = Informed



Previous

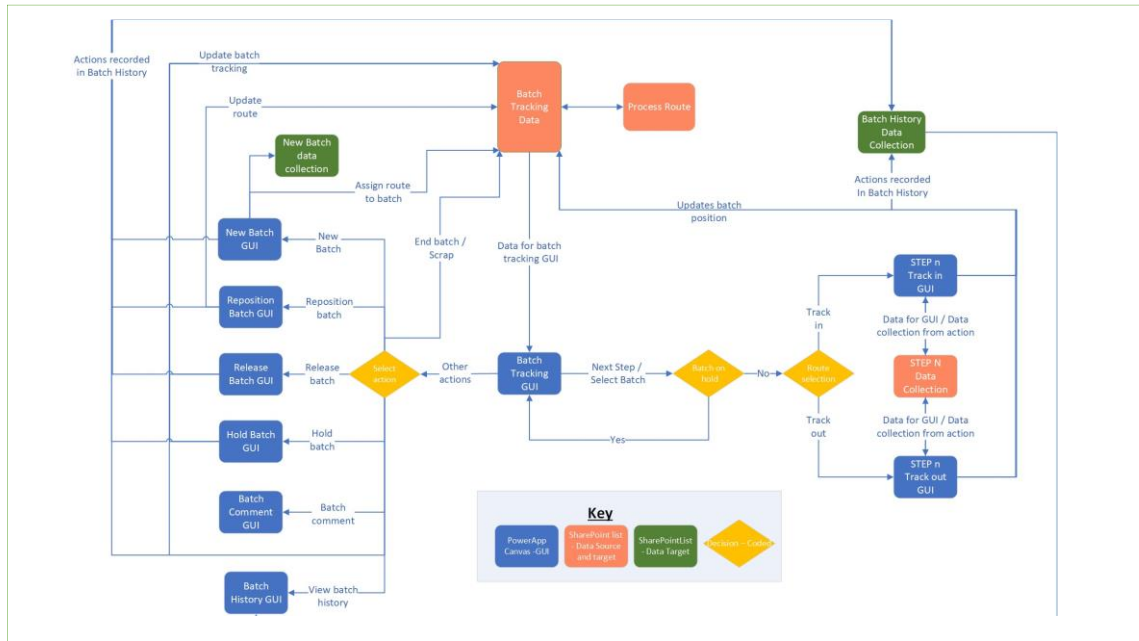
STEP 2

STEP 3

STEP 4

STEP 5

Next 8

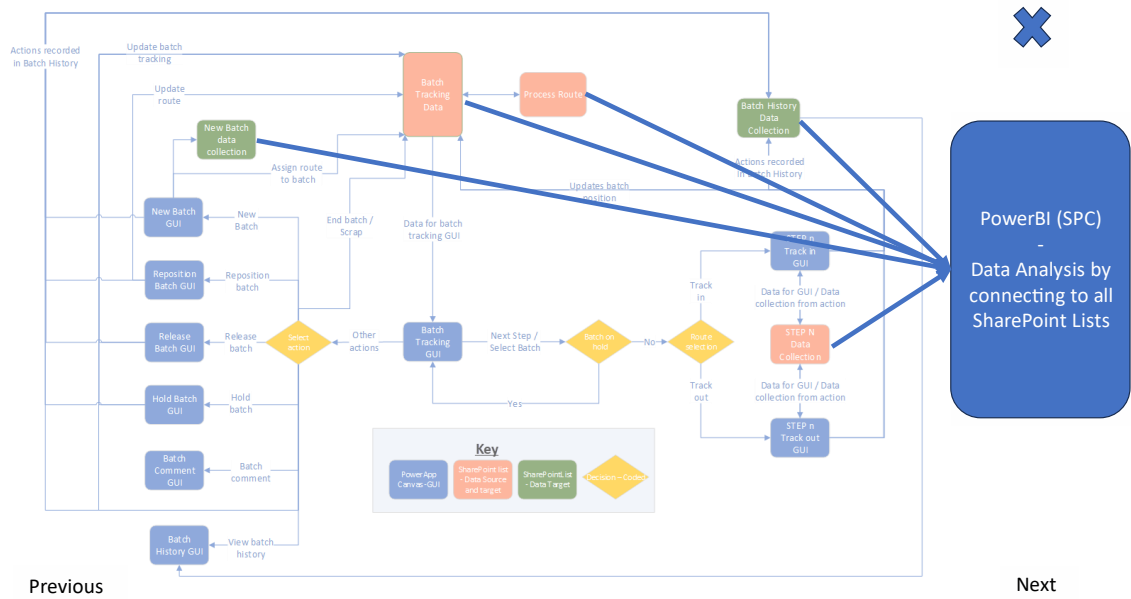


Gate 5/6 – Implementation Plan

R = Responsible, A = Accountable, C = Consulted, I = Informed

Objective – To develop a plan for a structured data collection system

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5
<ul style="list-style-type: none"> Creation of App 	<ul style="list-style-type: none"> Demo app for approval 	<ul style="list-style-type: none"> Training 	<ul style="list-style-type: none"> Big Bang - Implementation 	<ul style="list-style-type: none"> Data analysis planning
<p>Create and connect App GUIs and Sharepoint lists as detailed in architecture then test</p>	<p>Demo app to key stakeholder and gain approval (maybe a reduced version)</p>	<p>Train all operators on app</p>	<p>Release app to production environment with admin on hand to monitor</p>	<p>Initiate data analysis platform plan using PowerBI</p>
<p>Responsibilities</p> <p>Me – R / A Key Staff – R</p>	<p>Responsibilities</p> <p>Me – R/A Key Staff , Manager – C/A Available ops – C</p>	<p>Responsibilities</p> <p>Me – R/A All operators– A</p>	<p>Responsibilities</p> <p>Me – R/A All operators– A</p>	<p>Responsibilities</p> <p>Me – R/A</p>
<p>Outcome</p> <p>Creation of functional and tested app</p>	<p>Outcome</p> <p>Approval for release of app</p>	<p>Outcome</p> <p>Operators trained</p>	<p>Outcome</p> <p>Full release of structured data collection app - fabData</p>	<p>Outcome</p> <p>fabData analysis connection plan creation</p>



Gate 7

Objective – To develop a plan for a structured data collection system

Validity and Transparency	Credibility	Relevance	Logic	Direction
<ul style="list-style-type: none"> Plans followed (data collection) Evidence recorded of workshops CSA and CFW research outcomes present in solution Approved final plan for a structured data collection system 	<ul style="list-style-type: none"> Multiple published sources used for research (10) to gain different insights Multiple key stakeholders involved in creating the proposal Multiple key stakeholders and methods involved in data collection rounds Approval from multiple key stakeholders 	<ul style="list-style-type: none"> All stakeholders including management are excited to learn more about the completed system 100% accepted structured data collection plan People want the change (change management) Future benefits recognised 	<ul style="list-style-type: none"> Logical structured approach to thesis (gate system) Enthesis on logical system architecture Logical visualisation for final proposal Logical connection between gates 	<ul style="list-style-type: none"> Clear direction given to stakeholders at company X and detailed in the thesis Other people onboarded for future stages (data analysis) due to change management effect.