



DESIGN & DEVELOPMENT OF A REAL-TIME COIL QUALITY MONITORING SYSTEM FOR TATA STEEL

Industrial Research Proposal (ACCB6029)

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1. Background

1.1. Industrial Context

Steel manufacturing is a complex industrial process that transforms raw materials into finished steel products with specific mechanical and surface properties. Within the surface inspection process, every steel coil must undergo quality checks to ensure that required specifications and benchmarks are met. These inspections must be accurate, as they enable operators to make informed decisions regarding the disposition and next steps of each coil. Failure to perform these inspections accurately may result in reduced product quality and production throughput, both of which are critical to maintaining customer satisfaction and controlling operational costs, respectively [1], [2].

1.2. Current Surface Inspection System

The current surface inspection process is controlled by a coil tracking application called 'TLR' (Tata Logical Release), which records production and inspection data that is displayed to the operator after a coil has completed processing. While processing, several inspections are performed, checking parameters such as surface defects, coating measurements and strip thickness. Data from inspection systems, sensors and cameras is then evaluated using predefined software checks. Once processing has been completed, operators review the coil inspection data and determine the appropriate disposition and subsequent processing route [3].

1.3. Limitations of the Current System

Despite the functionality provided by 'TLR', the delay in presenting this information until after processing has been completed means operators cannot respond to defects while the coil is still being processed. Defects requiring immediate action may only be highlighted once the coil has reached the end of the production line. For coils of several thousand metres, this can require the entire coil to be re-run so that the defect can be removed and the remaining strip re-welded. Unnecessary reprocessing can result in increased production time and manufacturing costs, while reducing operational efficiency and throughput [4].

1.4. Proposed Solution

This project proposes the development of a real-time coil quality monitoring system that enables production data to be collected, processed and displayed throughout the inspection process. The proposed system will utilise the existing ROC (Rework Optimisation Control) framework, a software application originally developed for a different operational purpose on an alternative production line within Tata Steel. While the ROC was designed to support another production process, its communication ports and data processing capabilities make it suitable for receiving and processing real-time production data. The project will extend the ROC framework to present live

information to operators, allowing defects to be identified and actioned as they occur, rather than after the coil has been processed. This could reduce unnecessary reprocessing while improving production efficiency and supporting more informed decision-making [5].

2. Literature Review

2.1. Industrial Software Systems

Supervisory Control and Data Acquisition (SCADA) systems are used within manufacturing environments to monitor and control production processes. They collect production data from industrial equipment and provide operators with a summarised view. SCADA systems integrate hardware, including sensors, actuators and terminal units, with software such as databases and Human-Machine Interfaces (HMIs) to store and display information [6]. This architecture demonstrates how data from multiple sources can be gathered and presented to support operator decision-making.

SCADA systems can also monitor and control industrial processes in real time, improving operational efficiency, reliability and safety [7]. Furthermore, Sama et al. [8] identify SCADA as a component used to acquire production data within manufacturing environments, highlighting its ability to simultaneously gather data from multiple sources. These capabilities are relevant to the proposed system, which will also receive production data and present current coil information while processing is ongoing.

2.2. Real-time Systems

Real-time systems allow production data to be collected and analysed as events occur rather than after processing. Hakam et al. [9] state that the increasing digitalisation of manufacturing has led to greater use of real-time monitoring, allowing production information to be continuously analysed and acted upon to improve operational efficiency and performance. Processing data as it is generated enables production events to be identified and acted upon more quickly, potentially reducing processing time and costs.

Modern manufacturing systems can also utilise an event-driven approach, where data is processed when a specific event occurs rather than at a predetermined interval. Ahmed et al. [10] describe the use of event-driven systems within steel manufacturing, where information from sensors and actuators is continuously processed to support operational efficiency. This approach reduces delays in decision-making, making it suitable for the proposed system, where processing would be driven by production events, such as defect identification and changes in processed coil length, rather than being delayed until coil processing is complete.

2.3. Data Exchange and Communication

Manufacturing environments often contain hardware and software systems that must exchange data despite using differing structures and communication methods. Chinnappen-Rimer and Hancke [11] investigated data transmission across heterogeneous client-server applications and developed a generic Extensible Markup Language (XML) model that provided a common interface for translating messages into the format required by each application. Their research demonstrated how XML can support integration by representing information in a standardised structure.

Similarly, Lau et al. [12] state that manufacturing applications require a consistent method of exchanging information. XML is described as a text-based, platform-independent format that can transmit data between different hardware and software platforms. These sources directly support the use of XML within the proposed system, where data from different inspection and recording systems must be structured consistently before being processed by the ROC framework.

2.4. Human-Computer Interaction

Human-Computer Interaction (HCI) focuses on how users interact with computing systems through interfaces to provide input and receive feedback. Hornbæk, Kristensson and Oulasvirta [13] state that interactive computing systems should be designed, implemented and evaluated with consideration for their users. They also highlight the importance of understanding users' needs and motivations, ensuring that the designed systems enable users to achieve their goals effectively and efficiently. The proposed operator dashboard must therefore support operators in monitoring coil progress, reacting to defects and recording actions.

Nielsen [14] identifies several principles for effective user-interface design, including “visibility of system status” and “recognition rather than recall”. Visibility of system status requires operators to remain informed about current coil status through continuously updated data. Recognition rather than recall encourages the use of clear labels, visible alerts and identifiable sections, reducing the information that users must remember. These principles support the proposed dashboard design, which will present live production information clearly and enable operators to respond quickly.

2.5. Inspection Systems & Quality Control

Automated surface inspection systems are increasingly being used within modern steel manufacturing to identify and classify defects. Neogi et al. [15] review vision-based steel surface inspection systems, which utilise cameras, illumination equipment and image processors to automatically identify and classify defects, addressing the limitations of manual inspection. The review identifies Parsytec as a commercial inspection system used within the steel industry, directly linking this source to the

proposed project, as Parsytec equipment is one of the proposed system's data sources.

Tang et al. [16] identify image acquisition, image processing, data management and human-computer interfaces as the main components of automated surface inspection. The inspection process involves image preprocessing, identifying and segmenting potential defect regions, extracting features and classifying the detected defects. They also identify real-time processing as an important requirement for surface inspection. However, steel inspection generates large quantities of data, requiring systems to balance speed, accuracy and reliability. The proposed system will utilise existing surface inspection and defect detection methods but will improve the speed and presentation of the resulting output, allowing operators to act upon defects while the coil is still being processed.

2.6. Summary

Collectively, the literature demonstrates that modern manufacturing systems can acquire, exchange and process information in real time. Automated surface inspection systems can process large quantities of inspection data to detect and classify steel surface defects, while effective user-interface design is essential for presenting this information clearly to operators. Additionally, real-time and event-driven approaches can reduce delays between data acquisition, processing and presentation, enabling operators to make decisions more quickly. However, defect detection alone does not ensure that actionable information is available to operators during production. The proposed system addresses this gap by integrating existing inspection sources within a real-time monitoring system that will present live production and quality information to operators while the coil is being processed.

3. Aim & Objectives

3.1. Aim

- Design and develop a real-time coil quality monitoring system that enables operators to monitor and action coils while they are being processed, reducing production delays and improving operational efficiency.

3.2. Objectives

- Investigate the current coil-tracking system and identify its limitations
- Review real-time manufacturing monitoring techniques and technologies
- Configure and implement the communication and data-processing components within the ROC framework to receive, transmit and process XML datasets
- Develop the logic required to validate, process and transform incoming production data into actionable information for real-time decision-making

- Design and implement a real-time operator interface for displaying processed coil information and defect data
- Evaluate the performance of the proposed system against the existing process

3.3. Success Criteria

- Successfully receives and processes incoming XML datasets without message loss or corruption
- Displays live coil information to operators
- Correctly identifies and displays defects through the operator interface
- Provides operators with sufficient information to action coils during processing
- Operates successfully for one complete coil-processing cycle

3.4. Minimum Viable Product (MVP)

- Receive XML datasets through configured communication ports
- Process XML data using C# logic
- Display live coil information and detected defects
- Record operator actions
- Operate successfully on a single production line for one complete cycle

4. Methods & implementation

4.1. Research Methodology

Research methodology is the systematic approach, methods and techniques used to investigate a problem. It should clearly define a research philosophy, approach, strategy, method and time horizon [17], [18].

The philosophy for this project is positivism, which focuses on observable and measurable facts through hypothesis testing. This philosophy is appropriate as the proposed system can be evaluated using measurable criteria, such as data processing speed, system reliability and defect detection accuracy [18], [19].

A deductive research approach will be implemented, which uses existing theory and knowledge to guide the system's development. This is suitable as the system will be developed based on existing production knowledge and real-time concepts before being tested against defined criteria [18], [20].

The primary strategy will be software development, supported by a case study of the existing system. This strategy is appropriate as the proposal will design, implement and evaluate a novel software solution. The case study will provide an understanding of the existing systems and operator requirements, ensuring that the proposed system will address the operational needs [18].

A mixed-methods approach will combine quantitative data, including processing times, availability, reliability and defect-identification performance, with qualitative operator feedback and observations [18].

A cross-sectional time horizon will be used to evaluate both the current and proposed systems and compare the collected data within a defined period [18], [21].

4.2. Requirements Gathering

The current system 'TLR' only provides defect information after coil processing has finished, reducing efficiency and throughput as a result of having to re-run coils to deal with defects. Data is recorded by line speed monitoring systems, IBA data recorders and Parsytec surface inspection cameras before being processed using several hundred C# rules, with the resulting information recorded in SQL tables and displayed to the operator through TLR. This introduces a delay between data acquisition, rule processing, storage and presentation. The proposed system must therefore process incoming data quickly enough to inform operators while the coil is still running.

The requirements of the proposed system are as follows:

- Must Have:
 - Receive XML data
 - Process incoming data
 - Display defect information
 - Allow the operator to action the coil
- Should Have:
 - Critical defect alerts
 - Coil map
- Could Have:
 - Historical action log
 - Advanced analytics
 - Predictive quality monitoring

Additionally, the proposed system must provide reliability, ease of use and accurate defect detection while remaining suitable for an industrial environment. These requirements were identified through observation and consultation with production operators, software engineers and management personnel, and through analysis of existing system data.

4.3. Design & Implementation

The proposed system will be designed to satisfy the requirements identified in Section 4.2, providing operators with real-time visibility of coil information. The design will focus on how data will be acquired, processed and presented in real time.

Production data will be acquired from data recorders, surface inspection systems and other monitoring equipment. Information from these sources will be converted into XML messages and transmitted through the ROC framework using configured input ports.

Once received, the XML datasets will be validated and processed using C# rules. This logic will evaluate incoming data against predefined conditions and criteria, allowing defects to be identified while the coil is running.

The processed information will be transmitted through an output port and displayed on the operator dashboard. The dashboard will present live coil information, including defect locations, alerts and coil status, allowing operators to react before processing is complete.

4.4. Data Collection & Analysis

Both qualitative and quantitative data will be collected and analysed to evaluate the effectiveness of the proposed system. Quantitative data will be obtained from system logs and production data, including XML message processing times, system availability and defect identification performance. This information will be analysed using statistical techniques such as averages and percentages, allowing comparison against the existing process and the project's success criteria [22].

Qualitative data will be collected from observations and operator feedback during testing. This will allow the usability of the dashboard and the effectiveness of the system in aiding operator decision-making to be assessed [23].

4.5. Testing & Evaluation

Testing will be conducted throughout development to verify that the proposed system functions correctly and reliably. Unit testing will isolate individual software components and processes before integration. These unit tests will verify XML construction and deconstruction, communication port configuration and data-processing logic. Integration testing will then confirm that the communication, processing and dashboard components operate correctly as a complete system [24].

The system will be evaluated against the success criteria in Section 3.3. Reliability and processing speed will be compared with the existing process, and operation will be assessed throughout an entire coil-processing cycle.

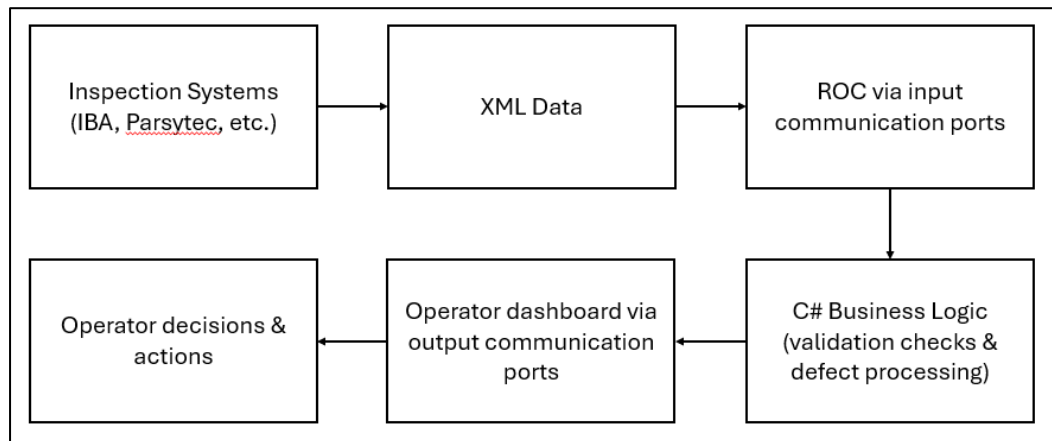
4.6. Materials and Resources

The project will use existing hardware and software resources within Tata Steel. Software resources include the ROC framework, Visual Studio, SQL databases, and the C#, SQL and XML technologies required to develop the system and its processing logic.

Hardware resources include a development PC, production servers, network infrastructure and access to the relevant inspection systems and their production data.

5. Project Design

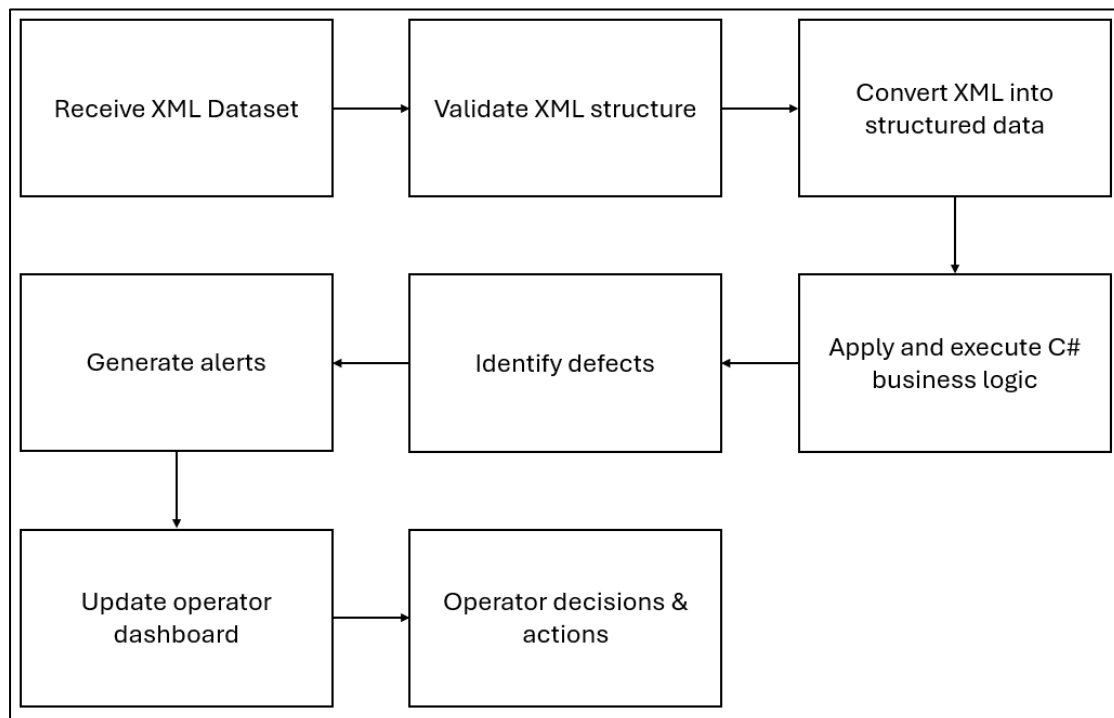
5.1. System Architecture



(Figure 5.1.1 – A flowchart of the proposed system architecture.)

Figure 5.1.1 demonstrates the proposed system architecture. Production data is generated by inspection systems, including IBA data recorders and Parsytec surface inspection equipment, before being converted into XML datasets. The XML messages are transmitted through configured ROC input communication ports, where they are validated and processed using C# logic. The resulting information is transmitted through output ports to the operator dashboard. The dashboard presents live production and quality information, enabling operators to make informed decisions and take corrective action while the coil is being processed.

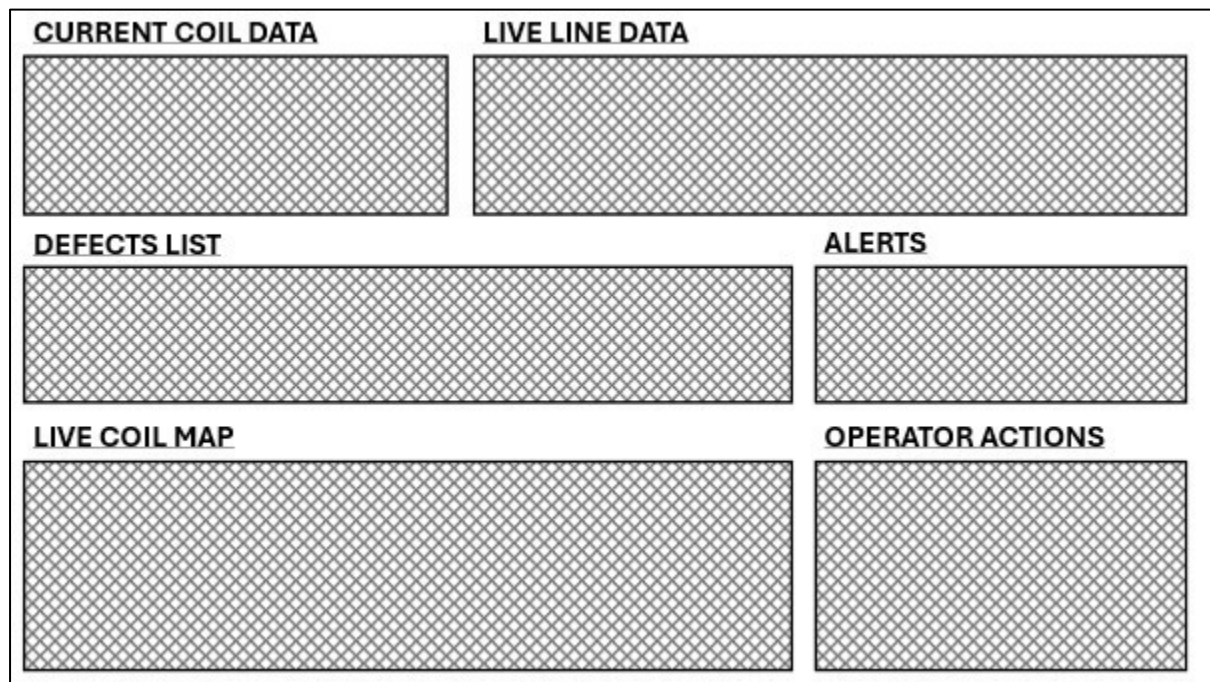
5.2. System Workflow



(Figure 5.2.1 – A flowchart of the proposed system workflow.)

Figure 5.2.1 demonstrates the proposed system workflow. An XML dataset is received by the ROC and validated to ensure the message is complete and correctly structured. The XML data is then converted into a suitable structured format for processing using C# logic. The C# logic then applies validation rules and defect detection criteria, with any identified defects being highlighted through appropriate alerts before the processed information is displayed on the operator dashboard. Operators can then review the live information and record actions for the current coil.

5.3. Operator Dashboard Mock-up



(Figure 5.3.1 – A wireframe diagram of the operator dashboard.)

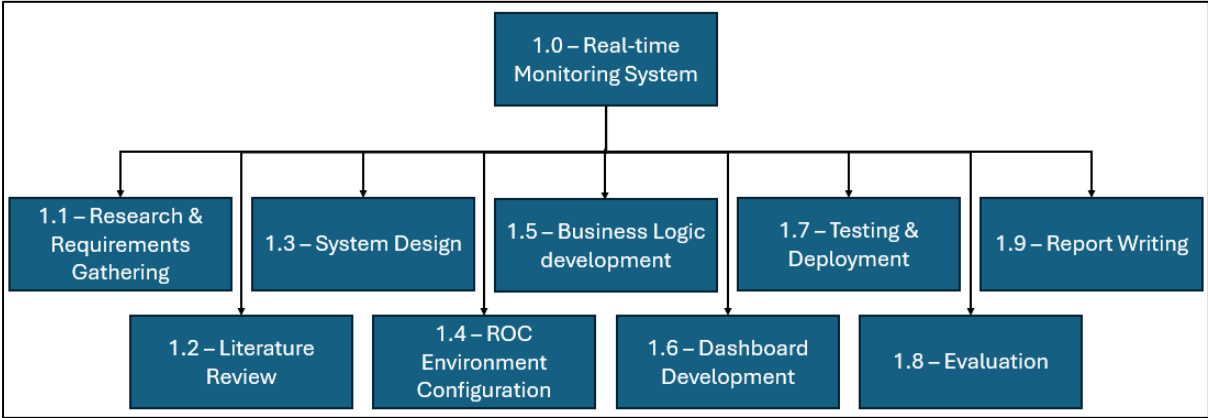
Figure 5.3.1 presents a wireframe of the proposed operator dashboard. The dashboard is divided into six sections, each providing information to aid operator decision-making:

- The 'Current Coil Data' section provides unique information for each coil, such as coil number, order details and material information.
- The 'Live Line Data' section displays continuously updating operational information, such as line speed, line status and processed length.
- The 'Defects List' section lists defects in tabular form, providing information on their type, position, size and grade.
- The 'Live Coil Map' section provides a graphical representation of defects, displaying their locations on a continuously updating coil map.
- The 'Alerts' section highlights any passed or failed checks and critical defects.
- The 'Operator Actions' section allows operators to record decisions, comments and actions.

This layout presents critical information clearly, enabling operators to identify defects quickly and make informed decisions while the coil is being processed.

6. Project Planning

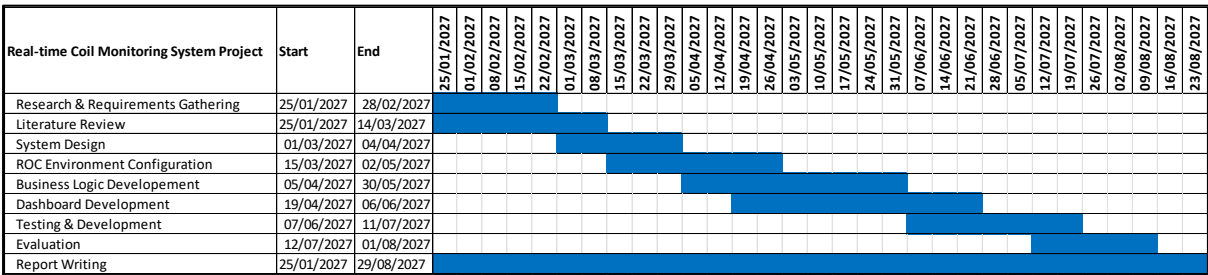
6.1. Project Tasks & Work Breakdown Structure



(Figure 6.1.1 – A work breakdown structure of the proposed project.)

Figure 6.1.1 presents the work breakdown structure for the proposed project. The project has been divided into nine tasks, beginning with research, requirements gathering and the literature review before progressing through system design, ROC configuration and software development. Once development is complete, the system will be tested and deployed before being evaluated against the success criteria defined in Section 3.3. The project report will be written throughout and finalised once the system has been deployed and evaluated [25], [26].

6.2. Project Timeline



(Figure 6.2.1 – A Gantt chart for the proposed project timeline.)

Figure 6.2.1 presents the identified tasks as a project timeline. The project progresses through research, design, development, implementation, testing and evaluation phases, with report writing undertaken throughout the project lifecycle. The Gantt chart also illustrates project milestones, represented by the completion of each task [25], [27].

6.3. Financial Considerations

As stated in Section 4.6, the proposed project will utilise existing Tata Steel resources, including the ROC framework, servers, integrated development environments (IDEs), databases and network infrastructure. Therefore, no significant expenditure on additional hardware or software is expected. The use of existing resources reduces costs while ensuring compatibility with existing systems. The primary costs will be development time, engineering and operator involvement, and the use of existing network and testing resources.

7. Project Impact

7.1. Industrial Impact

The proposed system is expected to provide several benefits. By providing operators with real-time production and defect information, defects can be identified and actioned while the coil is being processed rather than after processing is complete. This early defect identification could reduce unnecessary coil rework, helping to minimise waste and production costs.

The availability of live production information will support faster and more informed operator decision-making. This will enable operators to respond to defects and quality issues more quickly, potentially reducing delays and improving production throughput. This could reduce unnecessary coil re-runs, improve resource utilisation and contribute towards greater operational efficiency [4].

7.2. Limitations

Despite the benefits, several limitations must be considered. The proposed system is initially planned for deployment on a single production line, meaning that any improvements will be limited to this area and may not be immediately seen across other production areas.

The effectiveness of the proposed system is dependent upon the quality and availability of incoming production data. Inaccurate or incomplete data could affect defect detection, reducing the reliability of information presented to operators. Additionally, the system relies on existing network infrastructure and data sources. Network interruptions or data recorder failures could also affect the availability of real-time information, potentially causing operators' decisions to be based on incomplete or outdated information [28].

7.3. Future Development

Future development could focus on extending the proposed system to additional production lines following successful implementation and evaluation. A scalable design would allow the proposed system to be transferred to other production lines.

The operator dashboard could also be enhanced with more advanced data analytics, providing deeper insights into production performance and trends.

Further development could investigate artificial intelligence and machine learning techniques to support predictive quality monitoring and improve defect identification, potentially increasing operational efficiency and decision-making support [29].

8. Reflection

8.1. Learnings

Developing this proposal has improved my understanding of the research and planning required to undertake a major industrial software project. The literature review has helped to develop my understanding of industrial software systems, real-time monitoring, XML messaging, human-computer interaction and surface inspection. Investigating research methodologies has highlighted the importance of selecting an appropriate research philosophy, approach, strategy, method and time horizon. Additionally, analysing the existing process has increased my understanding of system requirements and the importance of understanding the needs of the user. Furthermore, the use of planning tools such as work breakdown structures, Gantt charts and MoSCoW prioritisation have helped me to improve my project planning skills.

8.2. Challenges

The main challenge will be developing a reliable system that can receive and process data from multiple sources without delays or incorrect information. As the dashboard will support operator decision-making, the information must be accurate and up to date. Integrating the proposed functionality into the existing ROC framework may also present difficulties, as the framework was originally developed for a different production process. These challenges will be managed through staged development and testing, alongside consultation with operators and software engineers to support a smooth transition from the old process to the proposed system.

8.3. Final Year Major Project

This project aligns with my current software development role, in both work and university studies, allowing me to apply my knowledge of C# to a production solution, while presenting opportunities to develop new skills in system integration, interface design, software testing and project planning. Although developing and implementing the proposed system within a production environment will be challenging, completing this proposal has increased my confidence that it is realistic and achievable. I am motivated by the opportunity to address a genuine operational problem and to develop a solution that could improve efficiency within Tata Steel.

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