Management of Electromechanical and Civil Design Interface in Railway Projects through Process Optimization Approach

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ABSTRACT

In this research, we defined Interface Management for Electromechanical and Civil Design Interface in Railway Projects by assessing the facts encountered in the Railway Construction industry to understand what are the causes and recommended solutions to electromechanical design interfaces could be, and providing an interface framework for parties to follow, so that the interface issues are appropriately managed, documented, resolved with practical engineering solutions, implemented, verified, and validated during the project life cycle.

This paper presented the data obtained from surveys and interviews conducted with individuals actively engaged in the Railway Industry and relevant research on Interface Management. This research aims to pinpoint the significant factors influencing and hindering the interface between electromechanical and civil design interfaces. Additionally, the study proposed an enhanced Interface Management System framework and streamlined Interface Coordination process for establishing the Type 3 Design Interface between Contractors. Significant factors in the Electromechanical and Civil Design Interface were validated using Statistical Analysis. The study presents an interface coordination approach focused on clear understanding design documents, integrating new technologies, materials, and construction processes, and optimizing efficiency in time, cost, and quality.

Keywords: Interface, Railway Engineering, Interface and Coordination, Construction Management, and Interface framework

INTRODUCTION

Background of the Study

Process Optimization, as defined, is the development of a process or methodology for making something such as a design, system, or decision as entirely perfect, functional, or effective as possible [22].

In the construction industry, Interface Management is defined as "the management of communication, coordination, and responsibility across a common boundary between two organizations, phases, or physical entities that are interdependent" [8].

This paper is a study of Interface Management in Railway Construction projects. Despite the management plans and procedures in place, certain issues still arise affecting interfaces among construction entities, mainly in electromechanical and civil design, resulting in interface issues (i.e., delays, changes, etc.).

In this research, we will define the Management of Interfaces for Electromechanical and Civil Design in

Railway Projects by evaluating the issues encountered in the Railway Construction industry to understand the causes and what recommended solutions to electromechanical design interfaces could be, and by formulating an interface framework for parties to follow, so that the interface issues are appropriately managed, documented, resolved with practical engineering solutions, implemented, and validated during the project life cycle.

Railway Construction interfaces are generally classified into five different types from Type 1 to Type 5, as shown in Table 1.

TABLE 1 CLASSIFICATION OF DIFFERENT TYPES OF INTERFACES FROM TYPE1 TO TYPE 5

Interface type	Details of Interface
Type 1	Internal interfaces within the contract packages within the Organization or the same Contractor that covers Electromechanical Systems only
Type 2	Interfaces between the contract packages of Rolling Stock and Electro-Mechanical (E&M) Systems
Type 3	Interfaces between the contract packages (of different contractors) of Electromechanical Systems with Civil packages
Type 4	Interface between the contract packages of civil packages
Type 5	Interface between contract packages with third parties (i.e., authorities, utility companies, and other stakeholders

OPTIMIZING TYPE 3 INTERFACE FRAMEWORK

Type 3 interfaces are related to the civil provisions for E&M installation, such as opening, spatial accommodation of E&M equipment, cable routing, locations of service points, and earthing points, among others.

The interface and coordination meeting between Contractors shall be a platform to allow both Contractors to share their work program and identify which activities require attendance from matching Contractors such as inspection of civil provisions, delivery route, etc.

Interface and coordination meetings cover interface issues, interface documents status and work progress. The interface team is required to conduct interface meetings where underlying interdependencies are explained and overseen. In these meetings, key personnel are required to attend.

The task to address the design, manufacture, supply, installation, testing and commissioning program the interfaces to meet the key dates of each contract, and highlight any program risks requiring attention. In the design process, dependency on interfacing systems is critical as the need to describe the work inspection process, detailed physical, structural, electrical, and mechanical drawings, and functional interfaces (such as protocols, software, and data structures) between interfacing parties.

The concern arises as to who will take the lead in producing combined services drawings, whether it is a Civil contractor or Electromechanical System Contractor.

As electromechanical system is design and build contracts, the development of combined service drawings comes in, and producing design in different stages starting from preliminary design to final design. Due to different work schedules between the two interfacing Contractors, the schedule of combined service drawings shall be co-reviewed and agreed upon by both interfacing teams to work out a practical schedule for both Contractors.

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Influencing Factors on Type 3 Interface

In the evaluation of influencing factors, we mainly refer to the research of [39] and other influencing factors that have appeared in the literature related to Electromechanical & Civil Design Interface, while taking into account the practical aspects of Interface Management.

Recognizing the quantity of influencing factors and the length of questionnaires that can influence participants' responses, Influencing factors have been reorganized and regrouped accordingly. Twenty-three (23) influencing factors have been derived out of thirty-four influencing factors from Zheng's research on Interface Management of general Contracting Projects such as:

1) Inadequate intervention by the owner

2) Delays in the project payment/ kick-off

3) The construction party misunderstood the design documents

4) Use of new technologies, new materials, and new processes in construction

5) Inexperience of subcontractors

6) Lack of awareness of high-tech and smart construction

7) Errors in design drawings

8) Inadequate designer skills and experience

9) Design works ignore time, cost, and quality efficiency.

10) Design schedule delays

11) Unfamiliarity with Contract specifications, employer requirements, standards, and regulations related to the project.

12) Uncertainty and changes in the surrounding environment

13) Material/equipment supply delays

14) Change of Contract Price or requests for a variation order

15) There is no clear definition or description of the work of the interface class

16) Lack of communication between participants

17) Participants have different cultures or backgrounds

18) Poor information processing ability

19) Incomplete staffing

20) Lack of effective management and unified command

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21) Lack of available procedures or processes for managing Interface

22) Lack of effective oversight

23) Lack of Build Information Models (BIM) reference for the project

Definition of Terms

- **Civil Contractor**– Engaged in the design and construction of Civil works packages to deliver the whole project in accordance with the contract requirements.
- **Combined Services Drawing (CSD)-**A drawing showing the detailed coordinated installation location arrangements of E&M works on architectural layout background, including services routing and equipment layout inside a building.
- **E&M Contractor** -Engaged in the design and construction of Electromechanical Systems (e.g., Railway) packages to deliver the whole project in accordance with the contract requirements.
- **E&M-**Electrical and Mechanical System (i.e., Electromechanical System in Railway Construction Industry).
- **Engineer's Team** – Consultant. Responsible for monitoring the progress of Contractors' works and coordinating with Contractors for clarification of technical requirements related to the interface. Engineer's Team is usually referred to as the Consultant.
- **Interface Team**– Responsible for managing interface in type 3 interfaces to ensure the interface information throughout the project stages is exchanged with interfacing contractors promptly, including the production of coordination drawings which contain the agreed interfaces with technical details for subsequent construction and installation stages.
- **Interface Manager**—The interface Manager manages all interface activities with different design disciplines, departments, personnel, etc. The Interface Manager shall initiate communication, meetings, discussions, workshops, etc. with internal and external parties and ensure a healthy exchange of information between all parties.
- **Interface Solution Register (ISR**)-A document to record the agreed interface solution by interfacing parties.
- **Process Optimization**-Development of a process or methodology of making something such as a design, system, or decision as functional and effective as possible.
- **Request for Information (RFI)-**A specific document for use by the Contractor to seek clarification of technical queries over interface requirements from the Engineer's team.
- **Technical Requirement –** The technical requirements are documented information in the works contracts with the client or employer.

METHODOLOGIES

This chapter presented the research design, research area, approach to data gathering, approach used for data analysis, and research ethics encountered in addressing the research problem of managing Electromechanical and Civil Design Interfaces in Railway Projects.

Research Design

The reliable framework to Optimize the type 3 design interface between Contractors was assessed by analyzing the survey data gathered from the Railway Organization. Major issues were determined to formulate the best process optimization on the type 3 Design Interface based on statistical analysis.

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The research design described the following:

- **Defining Problems in the Management of Interfaces.** Problems encountered in the Management of Interfaces were defined to assess further the best possible solution for managing Interfaces between E&M and Civil Contractors.
- The demarcation between Civil and System Contractors was analyzed.
- Responsible parties needed in the implementation of the Process Optimization Approach were identified (e.g., Interface Manager, Interface Engineer, Quality Engineer designated for Interface Issues, and Document Controller).
- **Assessment of Contract Documents.** In the hope of having a process optimization approach, contract documents were also visited to check any limitations on Type 3 Interfaces.
- **Analyzing Interface Coordination Processes.** Process flow for treatment of Type 3 Interfaces, including coordination, defined responsibilities for the management of interfaces, and defined workflows and document forms to use for interfaces throughout the design and construction stage.
- **Interface Solution Register** – A document that records the interface solution agreed upon by interfacing parties.
- **Works Inspection Process** – An optimized process of how the Contractor carried out inspections related to the interface.

Research Area

To effectively assess problems in interface management that would help this research in establishing the Process Optimization Approach in the Management of Electromechanical and Civil Design Interfaces in Railway Projects, the Type 3 interface areas covered in this research include Civil Works, Track Works, Signaling System, Telecommunication, Power Supply System and Distribution System, Overhead Contact Line System, and Depot Facilities.

Research Instrument

Survey and Interview

A survey was designed to measure the opinions and experiences of Railway Experts regarding factors that affect Electromechanical and Civil Design Interfaces. The questionnaire was given to them to identify the significant factor in the delay of the Type 3 Design Interface. Through this Survey, Major issues in the implementation of process optimization on type 3 Design Interface were measured.

Following the survey, interviews were conducted using the Delphi Method with Railway Experts. Guided questionnaires were used to explore their expertise and involvement in resolving Interface issues. These interviews aimed to deepen understanding of experts' roles and validate survey findings. Feedback on survey results was provided to experts, and subsequent interviews focused on uncovering insights not immediately apparent from the initial analysis, aiming to improve research clarity.

Ethical Consideration

The participating interviewees were fully informed of what has been included in this report and how the data are used. The participating interviewees were informed of their rights. Proprietary and confidential information are not included in the study.

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Participant data are kept confidential. Participation in the survey is anonymous. The researcher made efforts to preserve confidentiality by assigning code names that are used on all research notes and documents.

RESULTS AND INTERPRETATION

The consistency of the Likert scale was determined through Cronbach's Alpha with a target reliability above 0.90. The value obtained is 0.928 which indicates a very high level of consistency.

Analysis of Significant Factors Affecting Type 3 Design Interface

The T-test analysis is presented in Table 2 Analysis of Significant Factors Using T-Test (One-sided). Significant factors can be considered if the p-value is less than the significance level of 0.05.

TABLE 2 ANALYSIS OF SIGNIFICANT FACTORS USING T-TEST (ONE-SIDED

Influencing Factors in Type 3 Design Interface	Levene's Test for Equality of Variances		t-test for Equality of Means
	F	Sig.	Significance
Inadequate intervention by the owner	.004	.950	.371
Delays in the project payment	4.947	.034	.037
The construction party misunderstood the design documents	3.552	.069	.144
Use of new technologies, new materials, and new processes in construction	.021	.885	.277
Inexperience of subcontractors	.150	.701	.231
Lack of awareness of high-tech and smart construction	.000	.997	.248
Errors in design drawings	.000	.998	.254
Inadequate designer skills and experience	.220	.642	.416
Design works ignores time, cost and quality efficiency.	.014	.905	.009
Design schedule delays	2.845	.102	.332
Unfamiliarity with Contract specifications, employer requirements, standards, and regulations related to the project.	.092	.763	.346
Uncertainty and changes in the surrounding environment	.386	.539	.034
Material/equipment supply delays	2.198	.149	.044
Change of Contract Price or requests for variation order	.418	.523	.360
There is no clear definition or description of the work of the interface class	.191	.665	.303
Influencing Factors in Type 3 Design Interface	Levene's Test for Equality of Variances		t-test for Equality of Means
	F	Sig.	Significance
Lack of communication between participants	.152	.700	.261
Participants have different cultures or backgrounds	.126	.725	.135
Poor information processing ability	.080	.779	.387
Incomplete staffing	.816	.374	.095
Lack of effective management and unified command	1.456	.237	.460

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Lack of available procedures or processes for managing Interface	2.113	.156	.341
Lack of effective oversight	.014	.907	.154
Lack of Build Information Models (BIM) reference for the project	.001	.970	.461

From the result of the t-test (one-sided), the following list shows the significant factors:

1. Delays of the project payment, having a p-value of 0.037.
2. Design works ignore time, cost, and quality efficiency, with a p-value of 0.009
3. Uncertainty and changes in the surrounding environment, with a p-value of 0.034.
4. Material/equipment supply delays) are the significant factors, with a p-value of 0.044.

All other factors of delay do not significantly impact the Type 3 Design Interface.

Reliable Framework To Optimize Type 3 Design Interface Between Contractors

An assessment of a suitable framework to address the significant factors of delay in the Type 3 Design Interface was conducted.

Three related literature was used as a reference for the development of the framework for Process Optimization for Type 3 Design Interface, such as *The Interface Management System (IMS) framework* introduced in [11], *Object Model Framework for Interface Management in Building Information Models* [9], which covers process optimization technique focus on Build Information Modelling for Housing Industry; and *(3) Trust-Based- Interface Management Framework in* [31].

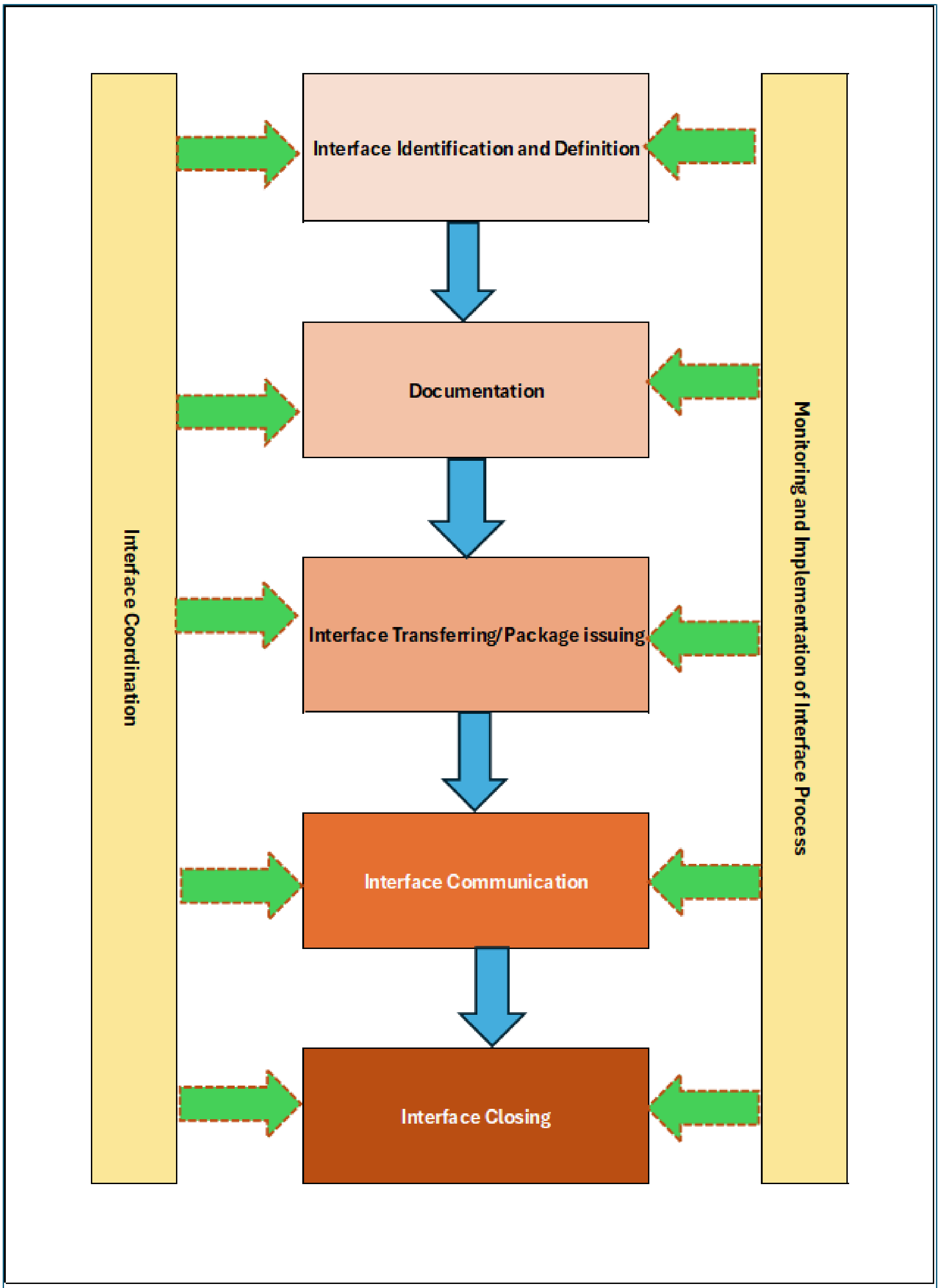
A reliable framework was established by adopting the Interface Management System (IMS) framework with further improvement and a focus on Interface Coordination and Implementation of Procedures at each step of the IMS Framework. Through this framework, we can optimize the process in the Type 3 Design Interface.

Figure 1 illustrates the Enhanced IMS Framework highlighting the following details.

1. **Interface Identification:** This step includes identifying as many interfaces as possible in the project.
2. **Interface Documentation:** This step defines the interface information, including the interface characteristics, involved parties, deadlines, needed documents, etc. Interface Documentation is a continuous step until the whole life cycle of the Interface Management System is completed. The RASCI matrix falls under Interface Documentation. RASCI stands for Responsible, Accountable, Support, Consulted, and Informed.
3. **Interface Transferring/Package issuing:** When the contract has been awarded, all the identified interfaces and their documented information are transferred to the appropriate parties.
4. **Interface Communication:** During this step, parties will start communicating with each other through the issuance of interface agreements to manage the interfaces effectively. This step will be executed under the jurisdiction of the Interface Manager and involve all interfacing parties.
5. **Interface Closing:** The interface is considered closed if all involved parties agree on the efficiency, accuracy, and completion of communicated information/tasks and deliverables
6. **Interface and Coordination:** This involves the exchange of interface information, handling of interface issues, and coordination activities throughout different project stages to ensure the interface matters are timely managed without affecting the progress of works to be executed by interfacing parties.
7. **Implementation of Appropriate Interface Processes:** This involves the exchange of interface

information, handling of interface issues.

FIGURE 1 ENHANCED IMS FRAMEWORK



Enhanced IMS Framework

A Way To Implement Process Optimization to Minimize Type 3 Design Interface Issues

Upon assessing the interviews with the participants, it became evident that the majority of responses highlighted the significance of (1) Delays of the project payment, (2)The construction party misunderstood the design documents, (3) Use of new technologies, new materials and new processes in construction, and (4)Design works ignores time, cost and quality efficiency. .

Based on the discussion with participants, it was notable that various RFI were unresolved or incomplete due to the absence of the E&M Contractor. Also, there is uncertainty about who is responsible for developing combined service drawings.

It is recommended that for Railway Projects, the responsibility for who makes the Detailed Installation Location Drawing or Combined Service Drawings be defined.

Given this fact, the researcher further developed the IMS Framework and produced a process flow as shown in Figure 2, that would address the need for implementing process optimization.

Hence, the data collected shows that quality engineers show little participation in Interfaces. To have effective interface management, the quality team shall conduct a regular audit to monitor the quality of interface management. Respondents also provided the following feedback, particularly in quality assessment matters:

1. The Interface Solution Register (ISR) is the agreed-upon detailed interface between E&M and the Civil Contractor, which becomes an interface requirement to comply with. The method of issuing the ISR to the Contractor at the commencement of works has not been determined.
2. A suggestion for a continuous coordination process
3. Unfamiliarity with the Interface process as people come and go in the project, familiarization with the interface process is being overlooked, the key person handling the interface for each stakeholder must be briefed and informed on the interface management process.

CONCLUSION

Significant Factors of Type 3 Design Interface

The findings highlighted significant factors such as Delays in project payment, design works ignoring time, cost, and quality efficiency, Uncertainty and changes in the surrounding environment, and Delays in material/equipment supply. These factors were identified through the T-test.

To enhance interface management, a reliable framework was proposed based on existing models such as the Interface Management System (IMS) framework and Trust-Based Interface Management Framework. The enhanced IMS framework covers key aspects, including interface identification, documentation, communication, coordination, and implementation of appropriate processes.

A Way To Implement Process Optimization to Minimize Type 3 Design Interface Issues

The study provided recommendations for implementing process optimization to minimize Type 3 Design Interface issues. These recommendations included defining responsibilities for developing combined service drawings, establishing clear protocols for distributing the ISR and ensuring thorough briefings for key stakeholders to maintain continuity in interface management processes.

The whole interface coordination approach is designed to address the issue in terms of clear understanding of the design documents, Use of new technologies, new materials, and new processes in construction, and time, cost, and quality efficiency.

The delay of project payment/kick-off is not in Interface management control, in this aspect, endorsement from the relevant team is necessary.

Overall, the study underscores the importance of robust interface management practices in construction

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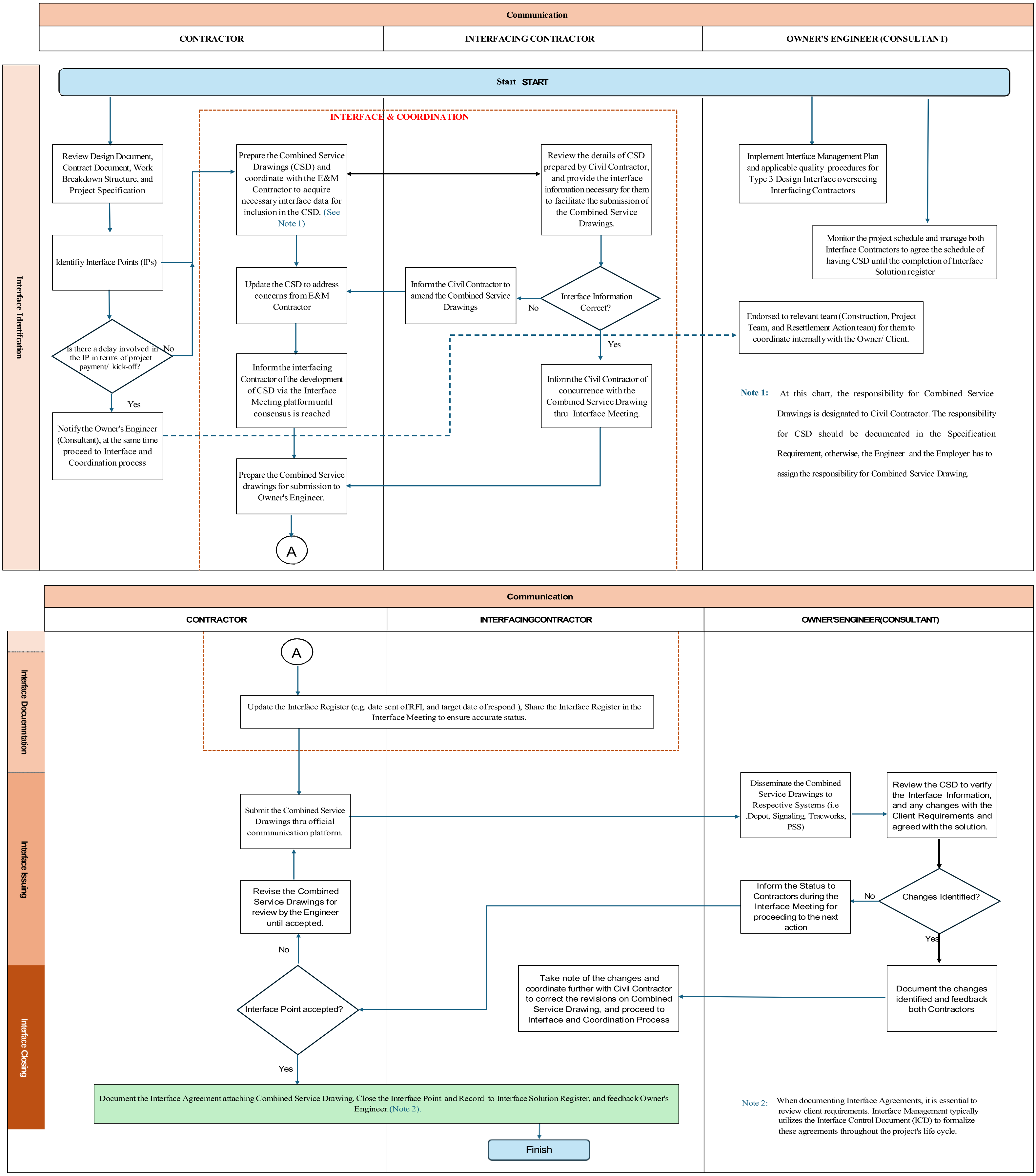
projects, particularly in addressing key factors that significantly impact the Type 3 Design Interface, and provides a comprehensive framework for optimizing interface management processes.

FIGURE 2 PROCESS TO MINIMIZE T YPE 3 DESIGN INTERFACE ISSUES



RECOMMENDATIONS FOR FUTURE RESEARCH

The structure of Interface management processes, Interface and Design Team together with Quality Team is responsible for establishing the necessary procedures for use by project members to suit the project stage during the project implementation. Moreover, the quality team should maintain the processes throughout the project.

While the four significant factors are the primary focus, it is important to note that in actual scenarios of the Type 3 Design Interface, all other factors often play crucial roles in decision-making. Ignoring them completely might not reflect practical considerations. It’s worth exploring whether any trade-offs between all factors could be optimized for specific goals. Additionally, further investigation might reveal nuances or interactions among these factors that were not initially apparent.

The root cause analysis also identified resettlement, which involves relocating people, as the primary factor causing delays in project payments/awards or kick-off. A focus group reveals that issues related to resettlement activities are significantly impacting the project timeline and, therefore, require future study.

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