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A FRAMEWORK FOR ENHANCING THE ENGINEERING REVIEW PROCESS IN OIL AND GAS EPC PROJECTS

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ABSTRACT

The construction industry, which has been for long suffering from schedule and cost overruns, is witnessing a growing focus on lean and digitalization as means to overcome process inefficiencies. However, the application of such concepts and tools in the specialized Engineering, Procurement, and Construction (EPC) Oil and Gas industry is still immature and lacks thoroughness. This paper illustrates how digital transformation and lean concepts can complement each other to enhance the engineering review process in a typical Oil and Gas EPC project. Namely, this study illustrates a unified platform that merges the traditional engineering document review stages and brings the stakeholders together for concurrent and collaborative engineering to reduce the nonvalue-added time in the process of engineering drawings review and approval. The platform shall act as a framework for Oil and Gas companies, based on which they can develop a flexible system tailored to their specific needs and requirements.

KEYWORDS

Obeya, oil and gas, engineering review, waste, collaboration.

INTRODUCTION

Engineering, Procurement, and Construction (EPC) is a popular contracting method adopted by the private sector to deliver large scale projects. Under EPC contracts, the contractor is responsible for the design of the project, detailed engineering, equipment and material procurement, construction, testing, commissioning, and sometimes the start-up of the facility for a fixed price and a fixed completion date. EPC projects in the Oil and Gas industry are characterized by their large sizes, uniqueness, intricate complexities, severe risks, and involvement of numerous stakeholders i.e., clients, contractors, suppliers, etc. (Rachman et al., 2018). The Oil and Gas industry currently faces daunting challenges as schedules and budgets are becoming tighter due to oil price high volatility and market instability. This industry has been plagued with waste and process inefficiencies that lead to significant cost and schedule overruns (Salama et al., 2008). To maintain competitiveness in today's challenging market, the industry witnessed a growing focus on waste elimination and efficiency improvements (Timilsina, 2017). The lean

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philosophy, which originated by Toyota out of similar challenges, can hence be a catalyst for improvement and a good tool to overcome the Oil and Gas industry inefficiencies.

Existing studies explored the synergies between Building Information Modelling (BIM) and lean and the advantages of applying lean and digitalization concepts in residential, institutional, commercial, and infrastructure construction projects (roads, highways, airports, etc.) (e.g., Tauriainen et al., 2016, and Koseoglu & Nurtan-Gunes, 2018). However, compared to other industries, the Oil and Gas sector remains one of the least mature world-wide in terms of digitalization (Fernandez-Vidal et al., 2022). Companies in the Oil and Gas sector have started to utilize various digital solutions e.g., Internet of Things (IoT), artificial intelligence, robotics and drones, wearable technologies (Wanasinghe et al., 2020), and software systems like Enterprise Resource Planning (ERP) (Gezdur et al., 2017). However, due to the numerosity and complexity of the processes in Oil and Gas projects, there is still a long way to go to reach maturity and reap the full benefits of digitalization and lean implementation (Rajagukguk et al., 2021).

This paper presents the application of lean tools and concepts along with digital initiatives to reduce nonvalue-added time in the process of engineering document review and approval in a typical Oil and Gas EPC project. Most Oil and Gas companies currently use traditional push methods for document preparation, review, and approval, where stakeholders work in silos and push the document to the next customer in the process with minimal collaboration throughout. Current digital solutions for the Engineering Review process are available in the form of Electronic Document Management Systems (EDMS) that aim at reducing paper usage. EDMS is a system that manages the flow of information, with the capability for storage, archiving, approval, monitoring, and control of documents to facilitate workflows (Pho et al., 2014). However, EDMS mimics the traditional push system but in an electronic form and hence does not address the dominant waste factors embedded in the process. This paper proposes a unified cloud platform that brings together all the stakeholders to allow concurrent work on Engineering documents, using live communication and collaborative commenting and review tools, resulting in shorter cycle times and less rework. This platform shall act as a framework for Oil and Gas companies, based on which they can develop a flexible system tailored to their specific needs and requirements.

LITERATURE REVIEW

The oil and gas industry is plagued with waste and process inefficiencies. 70% of activities in an EPC project are found to be non-value adding, which negatively affects productivity and profitability, causing project delays and cost overruns (Rajagukguk et al. 2021). The dominant waste factors during the Engineering phase, as identified by Rajagukguk et al. (2021) are: waiting for the needed documents, long and far meetings, waiting for feedback information, waiting for the document approval, producing document with outdated information, error of provided information, and producing dummy document to meet target. Lean philosophy is at the heart of value creation and waste reduction therefore several improvement methodologies for construction projects have been proposed in the literature based on its tools and principles. For instance, a study by Ko et al. (2014) analyzed the design workflow problems using the value stream mapping technique and showed that the systematic inspections of design correctness allow for the early detection of design errors and enhance the learning curve of team members. Tauriainen et al. (2016) studied the effects of BIM and lean construction on design management practices to increase efficiency of the construction process and reduce design errors and the number of review cycles. Their study emphasized the benefits of using the "big room" (otherwise referred as Obeya room) concept, where different designers work together on the same location to achieve a more effective information sharing among parties. This concept of impromptu sharing of information decreases the latency of decision making and shortens the overall design time. While it is well established that EPC performance can be improved by applying the lean construction model since it reveals the interdependencies of the Engineering, Procurement, and Construction phases (Ballard 1993), the application of lean concepts and tools in the specialized EPC Oil and Gas industry is still immature and lacks thoroughness. For instance, a systematic literature review by Rachman et al. (2018) on the state-of-the-art implementation of lean principles in the petroleum industry revealed that lean tools and techniques improved operational and technical aspects, contractor/supplier relationships, team organization and project management practice, and that the primary benefits included substantial cycle time reduction and cost savings. However, the authors found the subject to be still immature and lacking thoroughness in research methodologies as well as showing deficiency in the descriptions of the lean tools and techniques used.

Despite its challenges, digital transformation is a very promising topic in construction and in research, especially its synergy with lean practices. In the manufacturing industry, digitalization can be defined as the implementation of Information and Communications Technology (ICT) alongside data analysis (Lorenz et al., 2019). ICT enables organizations to gain a competitive edge in todays interconnected and highly competitive world (Pekarčíková, M. et al., 2019) and can improve the flow of processes, eliminate nonvalue adding steps, and shorten cycle times, rework, and errors (Von Heyl and Teizer, 2017). For large, complex, and repetitive-tasks projects, digitalization plays a key role. However, ICT inherently involves many complexities and if not used correctly could add to the process complexity (Bullock, S. et al., 2004). As such, the art is to integrate both lean and digital transformation to obtain an improved lean digital system (Lorenz et al., 2019; Stechert et al., 2020; Pekarčíková et al., 2019). A major area where digitalization supports Lean management is with largely distributed teams with different time zones where timely communication and exchange of information is essential (Stechert et al., 2020). Digitalization gives access to several communication and data-exchange alternatives such as commenting tools, emails, instant chat, and web conferences. However, having multiple digital platforms would confuse stakeholders and just introduce a digital mess, which accentuates the importance of integrating digital initiatives with lean philosophy (Stechert et al., 2020).

METHODOLOGY

This study adopted the design science research (DSR) methodology. This methodology entails the creation of a solution concept to address a set of challenges or to solve a practical field problem (Rocha et al., 2012). This study addresses the problem of the waste embedded in the engineering review process of a typical oil and gas project which is mainly identified through the authors' observations within their 22 years of combined experience in EPC oil and gas projects. The proposed solution was developed through a multi-step process that includes data collection, data analysis, and framework development. First, the process for the Engineering document review for the contractor engineering documents and the suppliers' originated documents was surveyed by accessing the Contractor's approved Standard Operating Procedure (SOP) from the Contractor's Quality Management System (QMS). The SOP titled "Preparation, Checking, Review, and Approval of Engineering Documents in Projects”, is a set of step-by-step instructions compiled by an organization to help its workers carry out routine operations and is followed by all personnel in the organization. It is to be noted that this is a generalized procedure for engineering documents review and is broadly followed by Contractors in the EPC oil and gas industry. The QMS is a formalized system that documents processes, procedures, and responsibilities. Three mid-sized oil and gas EPC projects (values of around $500 Million) located in Kuwait, Iraq, and Algeria and executed by the same EPC Contractor company were randomly selected for data collection, being representative of typical midstream EPC oil and gas projects with a typical set of Stakeholders (Client, Contractor, Suppliers, Subcontractors, etc.). Then, the transmittal data, which is recorded in the EDMS repository of each project, was extracted to Microsoft Excel, and grouped by category (contractor originated or supplier originated) and stage (based on the document review stages) to work out the average durations and the average cycle times per document category and for each stage. Collectively, the three projects had 10,000 engineering documents. Accordingly, the current state of a typical engineering document review process is mapped to show the various review stages along with the corresponding data. The collected data was then analyzed for waste identification. Finally, a framework is developed to help achieve an enhanced Engineering Review process. The following sections elaborate on each of those steps.

DATA COLLECTION

During the Engineering phase of an EPC project, the document review process may take prolonged periods in both interdisciplinary checks and client approvals. Critical documents undergoing many revision cycles are considered as constraints since they impact the schedule and cost of the project. A typical EPC project includes three main stakeholders involved in the Engineering phase: a contractor which is the responsible entity of all the involved Engineering, Procurement, and Construction phases, a client, and many suppliers. In order to improve the Engineering review process, the document workflow needs to be comprehended along with all the corresponding activities and interactions. This helps visualizing the bottlenecks and constraints in the process so that opportunities for improvement can be realized. The process flow stages for a document preparation, review, and approval, as detailed in the Contractor’s approved SOP are displayed in a flowchart form in Figure 1. Both Contractor and Supplier originated documents go through similar review and approval stages. But, if a document is being originated by the Contractor, the process starts with the preparation of the documents by the Discipline Engineer (DE) and ends with issuing it for design or releasing it for construction. If a document is from the Supplier side, it is prepared by the Supplier to be eventually either issued for design or released for the start of manufacturing. During the first review stage (i.e., Review Stage 1), the document which is either originated by the Contractor (by the responsible DE) or originated by the Supplier is reviewed by the responsible DE and by the Lead Engineer (LE) on the project. Every project is assigned one LE for each discipline (Civil, Mechanical, Electrical, etc.) and one or more DE to assist the LE depending on the workload. In the Review Stage 2, the document (if required) is issued for Interdisciplinary checking (IDC), whereby the responsible DE and LE (for the main document discipline) invite comments from other disciplines working on the Project. The originator then ensures the resolution of the comments from the other disciplines before re-issuing the document. For example, a drawing for a pressure vessel is the main responsibility of the mechanical engineering discipline. However, most pressure vessels include instruments (e.g., pressure and temperature instruments) that are installed on the vessel, hence some information and details for these instruments (i.e., bore size, flange rating, etc.) need to be communicated to the instrument discipline engineers, and vice-versa (i.e., comments from the instrument discipline engineers need to be captured on these drawings and communicated back to the mechanical discipline engineers to ensure incorporation by the vessel supplier). In Stage 3, the document (if required) is reviewed by Technical Authorities (TA) from the Engineering Department. Some documents may require additional review by an authorized person from groups other than the originating group. The originator shall then ensure the resolution of the comments before re-issuing the document to the next stage. For example, documents and drawings for high pressure turbine compressors are usually reviewed by TA who have more than 30 years of experience in turbines and compressors. This is required because of the criticality of such equipment for the plant operation, as well as the safety and commercial risks associated with them. In Stage 4, the document is issued to the Project Engineering Manager (PEM) for approval. Then, in Stage 5, the document is issued to the Client, either for information or for review and approval. In every project, a document review/responsibility matrix is prepared and agreed on with the Client in the initial 90 days of the project award date. This matrix specifies the review requirements for every document on the project. Some documents are not required to be reviewed and approved by the Client; hence, once complete, they would be issued to the Client for information purposes only and would not invite nor await comments from the latter.

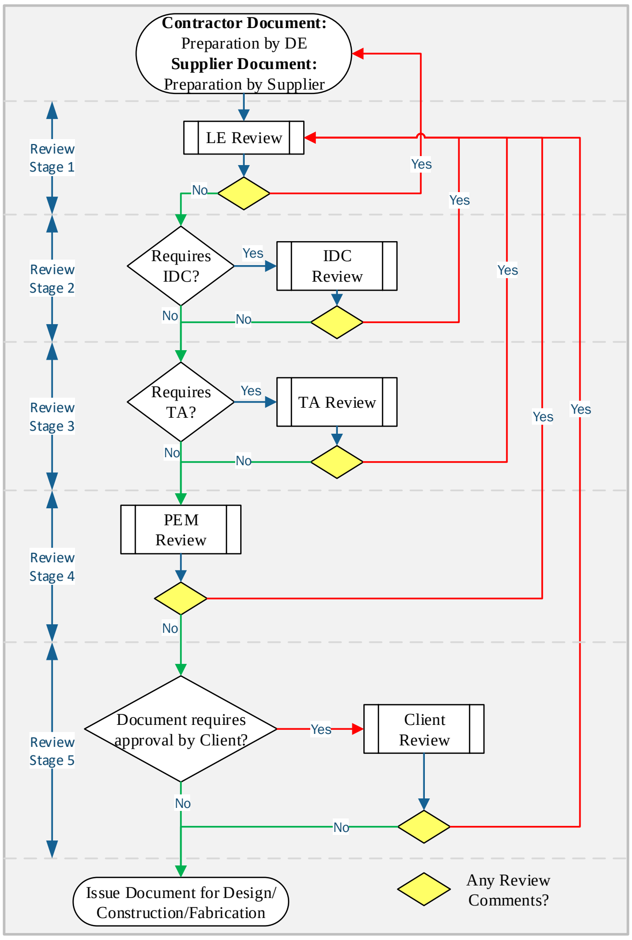

Figure 1: Document Review Process Flow Chart

The collected data is displayed in Table 1 and includes the average review time taken during each of the stages and the number of review cycles consumed by each document.

Table 1: Collected data

Category	Data	Duration (or Cycles)	Stage
Contractor Internal Reviews	Queue Time between "Start Draft" and "Issue for IDC"	up to 20 weeks	Stage 1
	Queue Time between IDC and "Complete IDC"	up to 2 weeks	Stage 2
	Queue Time between "Complete IDC" and "Issue to Client"	up to 3 weeks	Stages 3 & 4
Supplier Documents	Average number of Revisions	3 Cycles	
	Average Review Time by Contractor	2 to 3 Weeks	
	Average Review Time by Client	up to 2 weeks	Stage 5
Contractor Documents	Average number of External Revisions to Client	3 Cycles	
	Average Review Time by Client	2 to 3 Weeks	Stage 5

ANALYSIS

The data collected in Table 1 show a major issue with the contractor's internal review. The time taken between the start of a draft document, IDC, and issuance to Client can take up to 25 weeks; this does not reflect the value adding time actually required for this process (time that excludes waiting time i.e., waste or non-value adding time). The root cause analysis revealed that the main reasons for this unrealistic timeframe are:

- The push technique that is inherent in the traditional scheduling process for the Engineering phase imposes unrealistic dates. The Engineering schedule is usually developed in the first 90 days of the project award and is rushed to get approved without involving all the stakeholders in the planning process.
- The Rules of credit (ROC) for progress calculation for engineering deliverables is devised in a way to achieve maximum progress as early as possible because (1) progress is related with payments and (2) to cover delay in other planned deliverables. For instance, the ROC might stipulate 10% progress for each document by symbolizing the start draft milestone. The Contractor tends to record the start of working on the drafts in the very early days of the project just to secure an easy 10% payment; hence the long duration from "Start Draft" till "Issue for IDC", presented in Table 1.
- The technical documents prepared by the Contractor require a lot of information from different suppliers (e.g., foundation drawings require weights and footprint information from the suppliers of equipment) but are initiated without having sufficient information from the suppliers.

The documents generated by the Contractor can then take up to 3 weeks with the Client for approval. Supplier documents can take up to 5 weeks for review and approval, with an average of 3 review cycles. Most of this time is waiting time (waste i.e., non-value adding time) where the document is not actually being worked on.

The literature review highlights the importance of applying lean tools and concepts in the early stages of design to avoid cascading problems into the construction phase, reduce variability and waste, and add value to the customer. More importantly, the success of these tools, requires the commitment and buy-in of the involved stakeholders to guarantee transparency and information sharing. The following section presents the developed framework for enhancing the engineering review process in EPC oil and gas projects.

DEVELOPED FRAMEWORK

In a typical Oil and Gas EPC project, Stakeholders can include the Client and its project management contractor (PMC), the main Contractor and possible joint venture partners, Contractor Value Engineering offices, and the large number of Suppliers from bolt and nuts to massive gas turbine Suppliers (Badiru et al., 2016). The fact that Oil and Gas EPC projects are usually executed in different countries, time zones, and geographical areas, adds to the complexity of bringing those stakeholders together. Moreover, each one of these stakeholders usually have their own platforms and system adding waste and bottlenecks to move documents from one platform to another.

The framework in this paper presents a unified digital system or platform among all stakeholders that has collaborative commenting and review tools. This creates a digital Obeya room (Nascimento, D. et al., 2018) to resolve issues faster between the stakeholders and reduce nonvalue adding time, constraints, and bottlenecks in the documents review and approval process. The unified platform is accessible and operable by all stakeholders, eliminating the need for a document to go through different platforms. The platform features a list of all Contractor and Supplier originated documents and shows the whole life cycle of each document. The system enables live reporting and notifications which facilitates working in parallel and thus reduces the cycle times for each review stage. The platform also enables different stakeholders to communicate live with each other's, reducing delays due to conventional communication channels.

The framework in Figure 2 shows the different user-interface screens of the system and the navigation among them. The user starts by logging in to the system (User interface 1, Figure 2). A true single sign-on (SSO) feature is used so that the users will always be logged in to the system as long as they are using their operating system. This feature allows all stakeholders to stay online and available for any clarification needed, as if they are collocated. The user is presented with the option to choose the project he/she wants to login to from a drop-down menu, which features all the projects he/she is assigned to as per the Projects' Organizational Charts, Approval Hierarchy Charts, and the Responsibility Matrix. The responsibility matrix is created at the start of each Project, and it collects data from the Project Organizational Charts, Approval Hierarchy charts, and the Contract documentation requirements. It lists all the documents required as per the Contract along with the following attributes for each document: (1) the origin of the document (whether it is a Supplier or Contractor originated document), (2) the main discipline associated with the document, (3) the name of the main DE (Contractor) responsible for drafting the document, (4) the LE (Contractor) responsible for reviewing and approving the document, (5) whether the document requires a TA review and, if yes, the name of the TA approver (Contractor), (6) whether the document requires IDC review and, if yes, all the inter-disciplines applicable and the names of the inter-discipline engineers (Contractor) that are responsible for reviewing the document after the main DE(Contractor), and (7) the Client's Engineer's name responsible for the final review and approval of the document. The latter allows the document to proceed for fabrication (for Supplier initiated documents) or for construction (for Contractor initiated documents).

Once logged in, the system automatically detects the user's role on the specified project. The user can either go to the main screen to check his/her duties (i.e., User interface 2), or to the dashboard (i.e., User interface 3) to get updated on the overall progress. The main screen (User interface 2) then shows the user-specific notifications banner. For example, if a comment was assigned to the user on a specific document, it automatically appears in the notifications section where the user can either select to view the document and respond to the comment, or to close the notification. The main screen features also a table for “Pending Documents” and a table for “Documents Created (i.e., sent for review)”. These tables are linked and are continuously updated from the incorporated planning software database (from which it fetches dates and time milestones/deadlines) and from a responsibility matrix (from which it fetches the roles and responsibilities of the user). The “Documents Pending” table shows the documents that are pending for the user to initiate and start the reviewal process on, based on their role as per the responsibility matrix. The two actions available for the user are “Initiate” and “Delete”. The Delete action allows the user to delete a document which is deemed unrequired; this could be due to redundancy of information for example. The delete action will then send a notification for the next approvers to confirm. As for the “Initiate” action, the user clicks on it upon preparation of a document; accordingly, the document moves to the “Documents Created” table and is assigned the “under review” status. All respective stakeholders are accordingly notified that the document has been initiated. This action allows the dispatch of the document for concurrent review by all responsible users, ignoring the traditional stage/phase wise review and allowing all responsible stakeholders to collaborate and comment concurrently in one big digital room, simulating a digital Obeya room. The “Documents Created” table shows all the documents that have been initiated, along with their due dates, their statuses, and all possible actions that can be taken. Only the possible actions that are associated with the document’s status and role of the user can be shown in the “Actions” column. There are four possible statuses: “Pending Review”, “Pending Approval”, “Approved with no comments”, and “Approved with minor comments” (i.e., when a document is approved for manufacturing/construction but has minor comments that need to be resolved before the completion of manufacturing/construction).

If the document was “Pending Review”, the possible actions are “View”, “Edit”, “Delete”, “Issue for Approval”, “Resolve”, and “View History Log”. The “View” action allows the user to view the document and the comments. The “Edit” action allows the user to go back and edit the document based on the review and comments by the stakeholders. The “Issue for approval” action enables the initiator to issue the document for the next approvers; this is when all the comments are deemed responded to, actioned, and/or resolved. Additionally, the review period will be timeboxed as per the contract review cycle time agreed with the Client; consequently, the system automatically issues the document for approval once the review period is over. For example, if the review period is decided to be 21 days, then the document will have to be issued for approval within 21 days. Before 5 days of the deadline, the system sends reminders and notifications that the review cycle will be closed soon thus ensuring that all stakeholders finish their review on time. If a document exceptionally requires additional review time beyond the agreed review period (timebox), then a higher authority approval will be required, typically the Contractor’s and Client’s Project Directors and Managers. Also, the stakeholders will be able to monitor and control this through the dashboard where the document will be highlighted alerting that the deadline is close (within 5 days). The document will then be automatically issued for design/manufacturing/construction after all the approvals are obtained in the system. The resolve action is linked to the “Call for Conference” feature where it allows the user to choose and call one or more users that are assigned on the concerned document. This facilitates the communication among the involved stakeholders and the efficient resolution of pending comments. The "View History Log" action shows the tracking history of the document (including all comments and their resolutions/replies) from the moment it was initiated up until the current time.

If the document is pending approval, then the "Edit" action is no more available since the review process has already ended. The approved documents can have the following actions: "View", "Delete", "View History Log", and "Issue for Design/Manufacturing/Construction". Documents that are not directly used for manufacturing/construction but contain design information are issued for design (e.g., specification documents). The "Edit" and "View" actions from the main screen directs the user to the document screen (i.e., User interface 4). In this screen, the user may view the updated document, the comments created by the user, other stakeholders' comments, and also reply to comments assigned to him/her. All the actions performed on the Document View screen (i.e., User interface 4) are automatically recorded by the system and are therefore captured in a chronological manner in the history log of the document. This feature allows for an automated, easy, and transparent tracking of delays, which can be later used as backup documentation for any possible contractual claim.

The dashboard (User interface 3) is linked and takes critical data from the system's database, to help visualize and enable easy monitoring and control of the status and progress of the Project's documents. The use of color cues and warning symbols helps alert all stakeholders, in real time, of any threats that need to be addressed and enables the mitigation of issues as soon as they arise. The dashboard is user friendly and customizable by the user, providing flexibility to meet all users' specific needs. It would be accessible to all stakeholders with appropriate access control. Moreover, the performance of all stakeholders is presented in terms of documents reviewed on time and those which are delayed. Furthermore, the dashboard can present tiles, percentages, and statistical figures to give the full situation in a glance.

CONCLUSION

The Engineering document review process in an Oil and Gas EPC project can be very time consuming and involves a lot of waste. This issue is inherent to the nature of the process, which is designed to be a push system (even through EDMS). After collecting actual data from three EPC projects, the process flow stages (along with the corresponding data) for a document preparation, review, and approval, were displayed to help visualize the bottlenecks and constraints in the process. The current state of the document review process was analyzed and the constraints in the different stages were pinpointed. Accordingly, a digital framework is developed to enhance the current situation. The framework presents a unified platform that combines the different stages of the document review and approval process and transforms the system into a pull system (simulating a digital Obeya room) that facilitates concurrent Engineering, collaborative work, and "just in time" information transfer among different stakeholders. Namely, the developed platform integrates lean and digitalization concepts to facilitate working in parallel and reduce delays due to conventional communication channels, thus reducing the cycle times for each review stage. The framework includes also a visual management component (i.e., the dashboard) that allows the systematic monitoring and control of the engineering documents' review cycles, enabling early detection of arising issues. Finally, the unified platform ensures a comprehensive and automated recording and extraction of the history logs, which establishes for indisputable proofs for any possible delay claims.

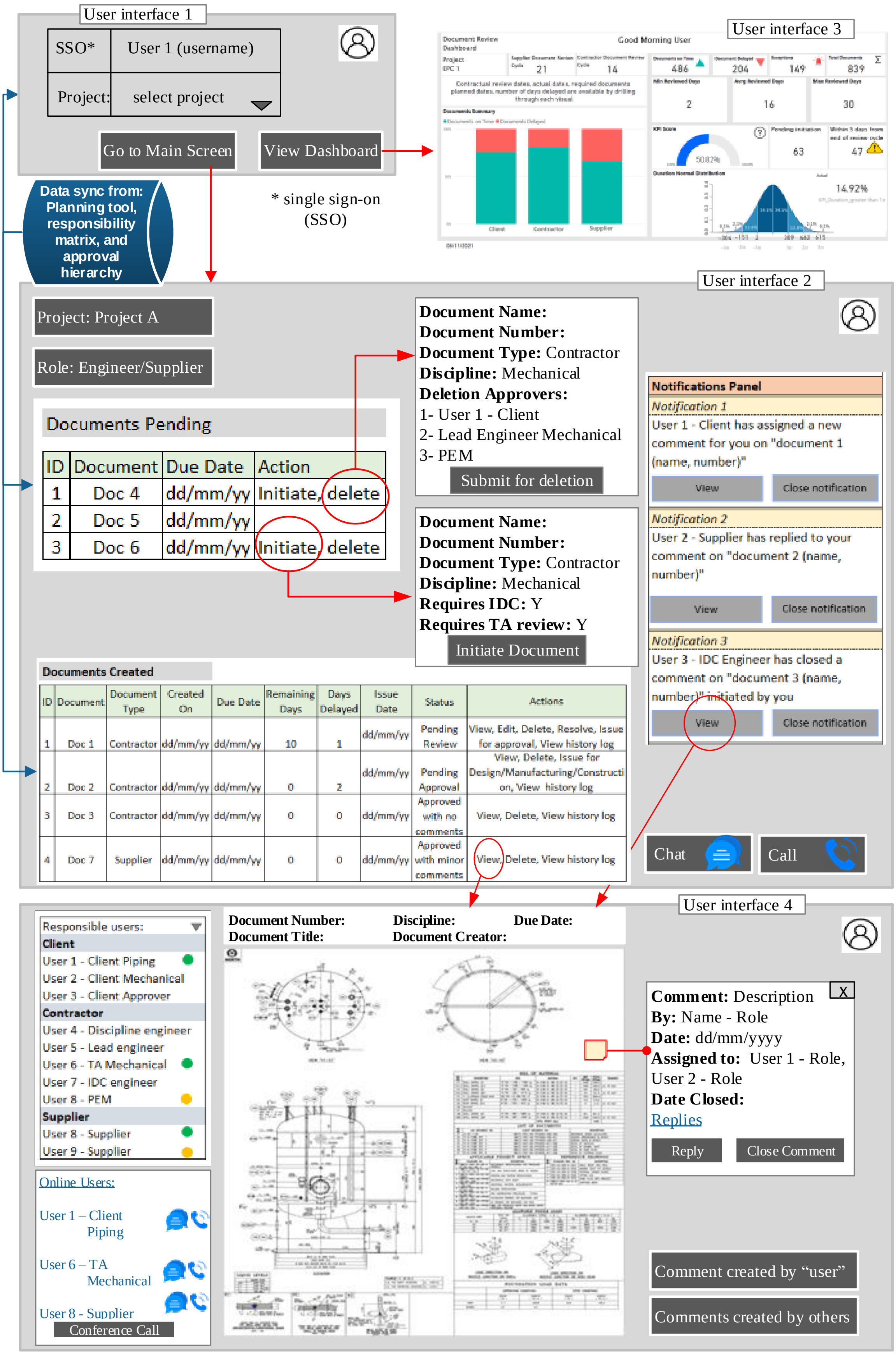

Figure 2: Unified Platform Framework

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