ISSN (e): 2250 – 3005 || Volume, 14 || Issue, 4|| Jul. - Aug. – 2024 ||
International Journal of Computational Engineering Research (IJCER)

Management System for Building Construction Rework With Predictive Data Analytics

Dr. Alvin C. Soguilon[1] Dr. Richard M. Pabelona Jr.[2]
[1]Project Manager,
Cebu Landmasters Inc.,
Cebu I.T. Park, 6000 Cebu City, Philippines.
[2]Associate Professor II,
College of Industrial Technology,
Main Campus, 6115 Talisay City, Negros Occidental, Philippines.

ABSTRACT
This study aimed to design and develop a Management System for Building Construction Rework with Predictive Data Analytics with the following technical features: a web-based collaborative platform, predictive analytics of project cost, project timeline visualization, and report generation. The system aims to predict the impact on project rework cost and time that affects the project budget and schedule and generates and prints project information on reworks. The Management System for Building Construction Rework with Predictive Data Analytics utilized the developmental and descriptive type of research method. The level of acceptability of the Management System for Building Construction Rework with Predictive Data Analytics was evaluated by construction practitioners and IT experts. There were twenty (20) respondents composed of fifteen (15) construction industry practitioners, these are consisting of construction project managers, engineers, and architects, with five (5) IT experts evaluating the system usability using the PSSUQ. The Management System for Building Construction Rework with Predictive Data Analytics was rated strongly agree and 100% functional and operational. It is acceptable in terms of usability, including system usefulness, information quality, interface quality, and overall usability. The system user manual was developed to provide assistance and guidance related to the usage of the developed system. Recommendations include deployment with a stable internet connection as web-based using any type of browser, upgrading the technical features that would suit the users' requirements based on minimum standards, and updating rework unit cost due to potential increase in material cost due to inflation. The Management System for Building Construction Reworks with Predictive Data Analytics provides valuable contributions to construction project practitioners for effective monitoring, planning, and mitigating the occurrences of project rework.
KEYWORDS: *Management system, building construction, rework, web-based interface, predictive data analytics.*

Date of Submission: 01-08-2024 Date of acceptance: 10-08-2024

I. INTRODUCTION

Reworks in construction projects are the outcome of the product that was not executed correctly according to the project plans and specifications. These are considered project quality issues and nonconformances that need to be resolved within the project execution phase.

Rework harms project performance, both directly and indirectly. The gross impacts of rework show an increase of 10% of the project cost (Manglekar, A., 2022) Most construction projects are completed unsuccessfully and most of the time perceived as a failure due to the impact of construction rework. Rework increases the project budget and drags the original project schedule way off the target (Dlamini & Cumberlege, 2021). It is noteworthy that obtaining the cost of rework is a key to understanding the nonconformance costs, also known as the cost of poor quality. The ability of construction firms to measure the cost of rework is essential for their survival in today's competitive environment (Mostofi et al., 2022).

Effective Collection and Sharing of Rework Information in Construction Process Using Smart Mobile. It is a web-based rework information management system that collects, shares, and manages the rework information by connecting functions of smart mobile. It is a mobile application that can save reports and search the project rework information generated during the construction stage. The users can access the system using their login credentials. The users of the systems are the construction personnel who can search the rework information and compare it to the quality management plan by using the computer and smart mobile at the construction site. (Cheol-Hwan Yoon, 2011). The existing system does not have email notifications to the users every time there is an update or new rework is added to the system. It only documents project reworks that compare to the project's quality management plan. The proposed system not only records the rework details but also quantifies the occurrences of rework, can predict the cost of rework, and shows the timeline to rectify the rework. It helps the users to plan for the actions to be taken to resolve the project reworks.

Project Rework Reduction Tool (PRRT) was developed by the Construction Owners Association of Alberta (COAA), Alberta, Canada. It was designed to assist project managers, project teams, and other stakeholders perform regular "health checks" of their industrial projects. PRRT has the capability of predicting and mitigating rework issues before impacting the project cost and schedule. It is easy to use, a practical software tool, and makes the project evaluation process easy. PRRT employs easy-to-use questionnaires in five identified factors that cause rework to rate the project performance. These five identified factors are: 1.) Engineering and Reviews; 2.) Construction Planning and Scheduling; 3.) Leadership and Communication; 4.) Material and Equipment Supply; and 5.) Human Resource Capacity (Team, 2007). The existing system only gives early warnings and predicts project problems based on the five identified contributing factors of rework. Although it is easy to use and makes the evaluation process easy due to the provision of charts, it requires personnel who have more experience in construction projects to use the system. Unlike the proposed system, experienced personnel is not necessary, it is quite simple to understand and operate the system. It requires recording the reworks based on the project nonconformance reports from the site personnel. Additionally, the existing systems are a web-based collaborative platform that records rework occurrences. It is capable of predicting the total cost of rework, automatically generating and showing the timeline and the possible amount of liquidated damages that provides a guide to the decision-makers.

The Touchscreen Entry of Construction Punch List Directly on a Plan, which is a system that establishes a construction punch list of a construction project for management and inspection. The users of this system are required to create an account before logging in and accessing the system. The construction plans such as architectural floor plans, electrical and plumbing plans, etc. are provided from a database in a central server to the project contractors and can be displayed using touchscreen devices such as mobile phones, iPads, and other touchscreen devices. The touchscreen devices are used to enter both graphical and textual color-coded or shape-coated construction deficiency data concerning the chosen plan (United States of America Patent No. 20120235944A1). The existing system only points out and shows the construction punch list in a graphical and textual form using the touchscreen feature. It does not produce data about cost and time for impact analysis of the project. A punch list is considered a minor defect with cost and time impact in the construction project that requires to be corrected before turning over to the end user. Whereas, the proposed system automatically provides the cost and time impacts of every recorded defect and shows the timeline and status as a guide for the users.

There have been numerous studies about the endemic problems of rework in construction projects. The topmost impact of reworks in construction projects are cost overruns and delays on the schedule. Some researchers have developed a web-based system that documents construction project reworks and defects and can be accessed online. However, these systems are considered only as a documentation and tracking tool for project reworks, it does not incorporate the cost of rework and the time to rectify the rework.

Thus, this study intends to develop a rework management and control system tool which is also considered a project quality measurement tool for all construction industry professionals and practitioners. This tool will be utilized to identify and classify rework occurrences; record and monitor reworks, calculate and predict rework costs and time delays while the project is underway; record the best corrective actions to be taken and its lessons for future reference; it also helps expedite the decision-making process of upper-level management to resolve the impact of reworks in the construction projects. This tool is necessary for building construction projects to mitigate cost overruns and schedule delays.

Objectives of the Study

This study is generally aimed at developing a Management System for Building Construction Reworks with Predictive Data Analytics.

Specifically, the study aims to:

1. Design and Develop a Management System for Building Construction Reworks with Predictive Data Analytics with the following features:
    1. Multi-user and Collaborative Web-Based Platform

   2. Predictive Analysis of Project Cost
   3. Project Timeline Visualization; and
   4. Report Generations
2. Test the functionality of the system in terms of the aforementioned features.
3. Evaluate the usability of the system in terms of:
   a) System Quality,
   b) Information Quality,
   c) Interface Quality;
   d) System Overall Quality
4. Develop the system's user manual.

II. Materials and Methods

This study develops a Management System for Building Construction Reworks with Predictive Data Analytics that must include the following technical features:

- Multi-user and collaborative web-based platform: The system is accessible through a web browser, enabling users to access the system from any device such as Android phones, laptops, and desktop computers with internet access. The administrators have overall control of the system. The staff can view and manage projects that were assigned by the administrator. The contractors can only view related projects assigned by the administrator.
- Predictive Analysis of Project Cost: The system can predict rework cost and timeline of rework items using the C4.5 algorithm Decision Tree Classifier predictive model. By providing the target work for each rework item, this rework item includes the owner-supplied materials (OSM) and non-owner-supplied materials (Non-OSM). The system can predict the cost and time of each rework item based on the productivity rate information from past data trained in the predictive model. The predictors are the reworked item name, unit, and target values. The variable to be predicted is the cost of rework together with the timeline.
- Project Timeline Visualization: The system displays rework items projected timeline in bar chart form that the users can view. After the prediction is given, the system will automatically give the estimated completion time and create a visualization of the timeline on the System Dashboard.
- Report Generation: The system can generate reports that are shown in the dashboard. The dashboard is the main reporting feature of the system. The following reports are the printable dashboard together with the rework and project timeline visualization. Furthermore, the system can give list reports of system modules such as the list of rework categories, staff, administrators, contractors, project information, and rework items. The reports can be exported to Excel and PDF or printed directly to the connected printer.

Research Method

The framework of Development and Technology research was utilized in this study. The goal of development research is to systematically examine the products, tools, processes, models, and systems to provide reliable, usable information to practitioners, theorists, and researchers (Richey & Klein, 2005). Utilizing descriptive statistics method to collect and interpret data will help explain and validate the results of this study to verify whether or not the system could benefit the organization. Kaliyadan, F., & Kulkarni, V. (2019), stated that descriptive statistics try to describe the relationship between variables in a sample or population and provide a summary of data in the form of mean, median, and mode.

It utilizes the Software Development Life Cycle (SDLC), which is an industry-standard process that ensures the production of software with the highest quality and lowest cost in the shortest time. A common understanding of the software development process is provided by the SDLC, which is a set of stages that describe how the software is created, from the business understanding and requirements elicitation phase to convert these business ideas and requirements into functions and features until its usage and operation to meet the business needs (Sami, 2021).

The Rapid Application Development (RAD) type of model of the SDLC was employed to develop the system. This methodology allows the fastest means to develop the system by focusing on the iteration of various rapid prototypes that capture the requirements of the user in terms of the functionality of the system (Powell-Morse, 2016). The RAD is suited to the project as cuts down development time, focuses on the process owner's feedback when developing project deliverables, allows integration at the start of the project, and enhances end-product risk management.

This method allows us to receive appropriate guidance and produce a better final product that satisfies the wants and needs of the stakeholders. The prototype that was created during the development can display the features that the stakeholder requested. The stakeholders had a better understanding of the system and could recommend features that were still unclear and weren't included in the prototype. They can also suggest processes that will be added to the system. The said approach of the model was vital as it provided a clear overview of the system and delivered a better development approach.

Respondent of the Study

The respondents of the study were taken from fifteen (15) construction project practitioners consisting of project managers, engineers, and architects, and (5) five IT experts. The total selected respondents were twenty (20) participants. Purposeful sampling was used to select respondents who were most likely to yield appropriate and useful information. It is a method for locating and choosing cases that will make the most efficient use of the limited research resources available (Campbell et al., 2020).

Data Collection and Analysis

Testing Phase

The researcher tested the system's functionality and usability with users to ensure that all of its components were functioning as expected and continued incorporating their feedback as the system was tested and retested for smoother and better performance. In this phase, it consists of the Initial Testing. The functionality of the system based on its technical features was tested using the test cases, and the Final Testing wherein the system's usability was evaluated by utilizing a standard Post-Study System Usability Questionnaire. The test cases in Excel file format were deployed to each respondent’s email address for their evaluation and requested to send back the accomplished form, while the PSSUQ was deployed using Google Forms and sent to each respondent’s email address for their online evaluation. The purpose of the study was explained to the respondents by the researchers.

Functionality testing

To ensure that the system operates according to the functional requirements and taking into consideration the design principles, functional testing is to be carried out (Dowson, 2015). A functionality test was conducted to test each function of the software application by providing appropriate input and verifying the output against the functional requirements. This testing checked the User Interface, Security, User/Server communication, and other functionality of the application under test. Test cases were used to test the functionality of the system, and it helped the users validate the system by rating the test scenarios, with expected and actual results, and with a pass or fail option, and comments section to help make sense of the rating.

Usability Testing

To test the usability of the system the standard Post-Study System Usability Questionnaire (PSSUQ) was used and administered to the respondents of the study. The PSSUQ has three versions, with the first two having 18 and 19 questions, respectively. It is the most widely used by many researchers on system development and design. It is used to measure users’ satisfaction with their perception of a website, software, system, or product right after the study (Lewis, 2018). The third version of the PSSUQ was used in this study and has 16 questions with four categories each, these are system usefulness, information quality, interface quality, and overall usability. It uses a 7-point Likert scale and includes a final not applicable option at the end. It is a Likert-type Seven-point Scale where 1 is the highest with the interpretation of "Strongly Agree" and 7 is the lowest interpreted as "Strongly Disagree."

The users evaluate the usefulness of the system by determining whether the system exhibits ease of usage, simplicity, and learning, and can successfully and efficiently complete the task using the system. These are the question numbers 1 to 6. Information quality is assessed by the users by examining the interaction of the system through the feedback of the system to them such as displays of error messages and steps to fix a problem within the system, and how the information within it is easy to comprehend and supervises the completion of the task. This is question number seven (7) to twelve (12). Interface quality is assessed by the users by looking at the level of meeting their needs based on the system’s features or capabilities. These are questions number thirteen (13) to sixteen (16). The last part is the overall usability of the system is evaluated by the users by asking them to describe their overall subjective reaction to using the system. As for the usability test results, the researcher used a statistical tool to significantly interpret them and compare them to the standard PSSUQ.

System Architecture

In the system architecture in Figure 1, the system user will use a computer to encode and receive all needed system information. The computer will then connect to a certain access point where it can send and receive the network packets to the cloud hosting server. The cloud hosting server will send the requested data to the database server and will send it back as data response to the access point and will be retrieved and displayed to the system’s user interface, enabling users to see and manage the processed information.

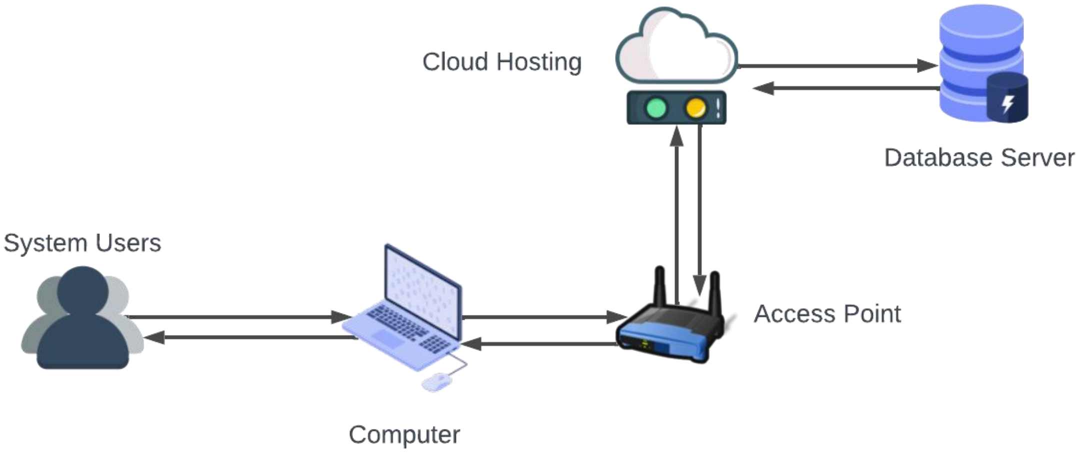

Figure 1. System Architecture

III. RESULTS AND DISCUSSIONS

The technical features of the system were achieved. The system is a multi-user and collaborative web-based platform. The users can access the system online with the internet by logging in which allows the user to enter their username and password. The system validates the username and password. Once it is valid, it allows the user to access the User's Account. The login page can be accessed by the administrator, staff, and contractor.

The system can automatically predict rework costs incurred on the project. This can be found in the dashboard that shows the particular project. It displays the project information summary, the result of predictive analytics on rework cost, a timeline of rework items, and the status of reworks.

The system displays the predicted timeline of each rework item in bar chart form. It shows the actual start date of doing the rework with remarks early and late start that identify the timeline status of the contractor. It also shows the work performed and the number of days remaining to complete the rework of the contractor.

The system supports the report generations of project reworks. It enables the users of the system to generate, view, and print reports on project rework costs on each project. The users can view and print reports with regards to a list of projects, contractor's information, categories, and items of rework. It enables the users of the system to generate, view, and print reports on project information about project reworks on each project. The dashboard is the main reporting feature of the system. The system can give a list of reports of system modules such as the list of rework categories, staff, administrators, contractors, project information, and rework items. The reports can be exported to Excel and PDF or printed directly to the connected printer.

Functionality of Technical Features of the System

Table 1 shows the test results of the test cases that addressed the technical features of the system. It also shows the test scenarios, test steps, test data, expected results, actual results, and the pass/fail remarks at the end. Based on the actual results, out of the twenty (20) primary users, including IT experts, the system had passed the functionality test with a pass remark.

Table 1. *Summary of Functionality Test Based on Test Cases.*

Test Case ID	Test Scenario	Test Steps	Test Data	Expected Results	Actual Results	Pass/ Fail
TC-1	Multi-user and collaborative web-based platform	1. Go to https://miracodes.com/rms 2. Enter Username (admin/staff/contractor) 3. Enter Password (admin/staff/contractor)	Username: admin Password: admin	Users will get access and be directed to the system dashboard.	Successfully log-in/accessed.	PASS
TC-2	Predictive analysis on project rework cost	1. Click on “Projects” 2. Choose the project and click “Reworks” to add new reworks 3. Click “New” and input the data/details of the new rework that will be predicted. 4. Click "edit" (pencil sign) to edit data/details of rework. 5. Click “Save” to generate the prediction.	Module-related information	Encoded Information should appear on the list.	Successfully added/edited information and appeared on the list	PASS
TC-3	Project timeline visualization	1. Hover “Dashboard” 2. Check the visualization column that views the timeline in bar chart form	Module-related information	Updates of the timeline start or actual date should reflect the changes in the bar chart.	Successfully show/view the bar chart in the dashboard.	PASS
TC-4	Report generations	1. Hover “Dashboard” 2. Choose either “Dashboard/Projects/Contractors/Categories/Items” whichever is applicable 3. On the chosen module choose to click “PDF/Excel/Print” to generate a report	Print report options	Users will be directed to print preview for printing/excel file format.	Successfully view the report on all the available options.	PASS

Usability of the System

The system usability was evaluated in terms of its usefulness, information quality, interface quality, and overall usability. The results are also compared to the PSSUQ-3 Norms, which show the lower and upper limits and mean for each question at a 99% confidence interval based on data from 21 studies with 210 participants that are analyzed at the participant level. Comparing the means of the current study to the designated ranges of the mean indicated in the PSSUQ Norm, serves as a reference for confirming whether the system complies with the industry's requirements (Lewis, 2018).

Table 1 displays the evaluation results, with items 1 through 6 measuring system usefulness, 7 through 12 measuring information quality, 13 through 16 measuring interface quality, and all items measuring overall usability. All means are within the range of 1.00 and 1.60, with an overall mean of 1.22, all of which are interpreted as strongly agree. The mean score of 1.22 for the Overall Usability of the system is higher than the mean score for the Overall Usability based on the PSSUQ Norm 3 which is 2.82. This result indicates that the system is acceptable to the standard requirements of the industry.

Table 1. *PSSUQ Evaluation Results.*

No.	Criteria	Average (Mean)	Interpretation
1.	1. Overall, I am satisfied with how easy it is to use this system	1.1	Strongly Agree
2.	2. It was simple to use this system.	1.05	Strongly Agree
3.	3. I was able to complete the tasks and scenarios quickly using this system.	1.25	Strongly Agree
4.	4. I felt comfortable using this system.	1.2	Strongly Agree
5.	5. It was easy to learn to use this system.	1.05	Strongly Agree
6.	6. I believe I could become productive quickly using this system.	1.2	Strongly Agree
7.	7. The System gave error messages that clearly told me how to fix problems.	1.6	Strongly Agree
8.	8. Whenever I made a mistake using the system, I could recover easily and quickly.	1.45	Strongly Agree
9.	9. The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.	1.5	Strongly Agree
10.	10. It was easy to find the information I needed	1.2	Strongly Agree
11.	11. The information was effective in helping me complete the tasks and scenarios.	1.15	Strongly Agree
12.	12. The organization of information on the system screens was.	1.15	Strongly Agree
13.	13. The interface of this system was pleasant.	1.2	Strongly Agree
14.	14. I liked using the interface of this system.	1.2	Strongly Agree

15.	15. This System has all the functions and capabilities I expect it to have.	1.15	Strongly Agree
16.	16. Overall, I am satisfied with this system.	1.1	Strongly Agree
	Overall Mean	1.22	Strongly Agree

Table 2 below displays the level of usability of the system as grouped according to its subscales: system usefulness, information quality, interface quality, and overall usability. The developed system has resulted with System Usefulness from items number 1 to 6 a result of 1.14, 1.34 for items 7 to 12 for Information Quality, and 1.16 for items 13 to 16 for Interface Quality, and System Overall Usability measured from all of the items numbers 1 to 16 have a result of 1.22. These are all interpreted as strongly agree.

The Overall Usability of the System obtained a mean score of 2.18 which implies that the respondents strongly agree that they are all satisfied with all the features of the system and that it can meet the stated or implied requirements.The PSSUQ results serve as the basis of the acceptability of the system.

The PSSUQ results serve as the foundation for the acceptability of the system, and the overall usability of the system received a mean score of 1.22, implying that the respondents strongly agree that they are all satisfied with all of the features of the Management System for Building Construction Reworks with Predictive Data Analytics and that it can meet the stated or implied requirements.

Table 3. *Subscale of the Usability of the System.*

Subscales	Criteria Covered in PSSUQ-3	Average (Mean)	Interpretation
System Usefulness	Items 1 to 6	1.14	Strongly Agree
Information Quality	Items 7 to 12	1.34	Strongly Agree
Interface Quality	Items 13 to 16	1.16	Strongly Agree
System Overall Usability	All Items	1.22	Strongly Agree

User's Manual

The system's user manual was developed, and the result shows the cover page of the user's manual of the system. The user's manual is created to assist and facilitate the users on how to operate the system. The system user's manual will guide the users in a step-by-step approach to how to access and navigate the system. It is a simplified form for all the users that makes them easy to understand.

Referring to the above results the following are the findings of the study:

1. The systems' technical features were developed and achieved as a web-based collaborative platform; predictive analysis of project cost; project timeline visualization and; report generation.
2. The functionality of the system based on the technical features was tested using test cases and remarked as pass, and is functional according to the technical features and helpful to the end users.
3. The level of usability of the system was evaluated the mean score of 1.22 implies that they are all satisfied with all the system's features and that it can meet the stated or implied requirements in terms of; System Usefulness, Information Quality, Interface Quality, and Overall Usability.
4. The User Manual of the system was developed and achieved as one of the outputs of the study and consists of a step-by-step procedure on how to use the system.

IV. CONCLUSIONS AND RECOMMENDATIONS

The overall results of the Management System for Building Construction Reworks with Predictive Data Analytics have distinct technical features that are user-friendly web-based collaborative platform interface for accessing and visualizing the collected data and information regarding building construction reworks, predict rework project cost and shows liquidated damages based on the encoded details of rework, displays rework project timeline in bar chart form, and generate reports of projects summary and status of rework using different print options such as pdf and excel file conversion. The system is a 100% pass, and it is fully functional and operational with a high index and is acceptable in terms of overall usability. It has also a conveniently developed user manual that provides assistance and guidance to the users on how to use the software system.

The following recommendations were formulated upon careful; consideration of the findings and conclusions of the study.

1. The system is recommended to be integrated with the building project construction process within the construction industry and will be deployed web-based and hosted by the company using Google Chrome or equivalent such as Firefox, and Microsoft Edge.
2. As for the predictive analysis of rework cost, this could be updated when there are changes in the unit cost of reworks as construction materials have the potential to increase concerning time and to consider the inflation rate.

3. Upgrade the system by improving and adding technical features through additional interfaces that would suit users' requirements and based on minimum standards.
4. This study should be published and shared with the construction industry community to motivate more improvement and solutions to the endemic problems of reworks in construction projects.
5. Further study on management systems for building construction rework with predictive data analytics to enhance leading to more accurate management systems for building construction reworks that improve decision-making, and effective project rework mitigation measures.

REFERENCES

[1]. Asenahabi, B. M. (2019). Basics of Research Design: A Guide to selecting appropriate research design. ResearchGate. https://www.researchgate.net/publication/342354309_Basics_of_Research_Design_A_Guide_to_selecting_appropriate_research_design

[2]. Bai, Y. (2023) Research on Civil Engineering Cost Prediction Based on Decision Tree Algorithm. (2023). Academic Journal of Architecture and Geotechnical Engineering, ISSN 2663-1563 Vol. 5, Issue 1: 39-44, DOI: 10.25236/AJAGE.2023.050107

[3]. Campbell, S. et al. (2020). Purposive sampling: complex or simple? Research case examples. Journal of Research in Nursing, 25(8), 652–661. https://doi.org/10.1177/1744987120927206

[4]. Cheol-Hwan Yoon, Do-Yeop Lee, and Chan-Sik Park (2011). Effective Collection and Sharing of Rework Information in Construction Process Using Smart Mobile. https://www.irbnet.de /daten/iconda/CIB_DC24401.pdf

[5]. Da, S., Ding, L., Zhong, B., Love, P., Luo, H., & Chen, J. (2020). Construction quality information management with blockchains. Automation in Construction, 120, 103373. https://doi.org/10.1016/j.autcon.2020.103373

[6]. Dlamini, M., & Cumberlege, R. (2021). The impact of cost overruns and delays in the construction business. IOP Conference Series, 654(1), 012029. https://doi.org/10.1088/1755-1315/654/1/012029

[7]. FineReport. (2021, December 24). Report Generation: Everything You Need to Know. https://www.finereport.com/en/reporting-tools/report-generation.html#:~:text=Report%20generation%20refers%20to%20the,informative%20insights%20and%20supportive%20references.

[8]. Finlay, S. (2014). Predictive Analytics, Data Mining and Big Data. Palgrave Macmillan UK eBooks. https://doi.org/10.1057/9781137379283

[9]. Gorla, N., Somers, T. M., & Wong, B. Y. (2010). Organizational impact of system quality, information quality, and service quality. Journal of Strategic Information Systems, 19(3), 207–228. https://doi.org/10.1016/j.jsis.2010.05.001

[10]. Gulghane, A., Sharma, R., & Borkar, P. (2023). Quantification analysis and prediction model for residential building construction waste using machine learning technique. Asian Journal of Civil Engineering, 24(6), 1459–1473. https://doi.org/10.1007/s42107-023-00580-x

[11]. Hartmann, J., Sutcliffe, A., & De Angeli, A. (2008). Towards a theory of user judgment of aesthetics and user interface quality. ACM Transactions on Computer-Human Interaction, 15(4), 1–30. https://doi.org/10.1145/1460355.1460357

[12]. ISO - Management system standards. (retrieved May 11, 2023). ISO. https://www.iso.org/management-system-standards.html

[13]. Kaliyadan, F., & Kulkarni, V. (2019). Types of variables, descriptive statistics, and sample size. Indian Dermatology Online Journal, 10(1), 82. https://doi.org/10.4103/idoj.idoj_468_18

[14]. Keenan, M. J., & Rostami, A. (2019). The impact of quality management systems on construction performance in the North West of England. The International Journal of Construction Management, 21(9), 871–883. https://doi.org/10.1080/15623599.2019.1590974

[15]. Kelleher, J. C., Mac Namee, B., & D'Arcy, A. (2021). Fundamentals of Machine Learning for Predictive Data Analytics. Fundamentals of Machine Learning for Predictive Data Analytics.https://openlibrary.telkomuniversity.ac.id/home/catalog/id/173989/slug/fundamentals-of-machine-learning-for-predictive-data-analytics.html

[16]. Kissflow, Inc. (2022). A Guide to Web Collaboration - Types, Benefits & Tools. Kissflow, Inc. https://kissflow.com/digital-workplace/collaboration/web-collaboration-guide/#:~:text=What%20is%20web%20collaboration%3F,effectively%20toward%20a%20specific%20goal.

[17]. Lewis, J. D. (2018). Measuring Perceived Usability: The CSUQ, SUS, and UMUX. International Journal of Human-computer Interaction, 34(12), 1148–1156. https://doi.org/10.1080/10447318.2017.1418805

[18]. Lintang, M., Pandiangan, N., & Hyronimus, D. (2022). Use of the C4.5 Algorithm to Analyze Student Interest in Continuing to College. Use of the C4.5 Algorithm to Analyze Student Interest in Continuing to College, 149, 01048. https://doi.org/10.1051/shsconf/202214901048

[19]. Manglekar, A. (2022). Rework Management in Construction Projects. International Journal of Advances in Engineering and Management (IJAEM) Volume 4, Issue 6 June 2022, pp: 2052-2056 ISSN: 2395-5252.

[20]. McIntosh, R. (2013, December 5. United States of America Patent No. 20120235944A1. Retrieved May 21, 2023.

[21]. Miranda, S., Del Rey Castillo, E., González, V. A., & Adafin, J. (2022a). Predictive Analytics for Early-Stage Construction Costs Estimation. Buildings, 12(7), 1043. https://doi.org/10.3390/buildings12071043.

[22]. Mohsen, O., Mohamed, Y., & Al-Hussein, M. (2019). Data Analytics application for Non-Conformance reports in a cabinet manufacturing facility. Modular and Offsite Construction (MOC) Summit Proceedings. https://doi.org/10.29173/mocs112

[23]. Mostofi, F., Toğan, V., Ayözen, Y. E., & Tokdemir, O. B. (2022). Predicting the impact of construction rework cost using an ensemble classifier. Sustainability, 14(22), 14800. https://doi.org/10.3390/su142214800

[24]. Nelson, R. R., & Todd, P. M. (2005). Antecedents of Information and System Quality: An Empirical examination within the context of data warehousing. Journal of Management Information Systems, 21(4), 199–235. https://doi.org/10.1080/07421222.2005.11045823

[25]. Olanrewaju, A. L., & Lee, A. H. J. (2022). Investigation of the poor-quality practices on building construction sites in Malaysia. Investigation of the Poor-quality Practices on Building Construction Sites in Malaysia, 14(1), 2583–2600. https://doi.org/10.2478/otmcj-2022-0008

[26]. Richey, R. C., & Klein, J. D. (2005b). Developmental research methods: Creating knowledge from instructional design and development practice. Journal of Computing in Higher Education, 16(2), 23–38. https://doi.org/10.1007/bf02961473

[27]. Rusyana, N. R., Renaldi, F., & Destiani, D. (2023). Prediction Analysis Of Four Disease Risk Using Decision Tree C4.5. Prediction Analysis of Four Disease Risk Using Decision Tree C4.5. https://doi.org/10.1109/iccosite57641.2023.10127710

[28]. Sami, M. (2021). Software Development Life Cycle Models and Methodologies. Mohamed Sami. https://melsatar.blog/2012/03/15/software-development-life-cycle-models-and-methodologies/
[29]. Team, P. E. (2007b). PRRT^{TM}: Project Rework Reduction Tool. https://doi.org/10.5703/1288284315860
[30]. Zeng, L. (2009). Designing the User Interface: Strategies for Effective Human-Computer Interaction (5th Edition) by B. Shneiderman and C. Plaisant. International Journal of Human-computer Interaction, 25(7), 707–708. https://doi.org/10.1080/10447310903187949