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BAHÇEŞEHİR UNIVERSITY

FACULTY OF ENGINEERING AND NATURAL SCIENCES

CAPSTONE PROJECT PROPOSAL

C-NIOSH-RWL

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STUDENT DECLARATION

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- they have given credit to and declared (by citation), any work that is not their own (e.g. parts of the report that is copied/pasted from the Internet, design or construction performed by another person, etc.);
- they have not received unpermitted aid for the project design, construction, report or presentation;
- they have not falsely assigned credit for work to another student in the group, and not take credit for work done by another student in the group.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

C-RWL-NIOSH	Computerized-RWL-NIOSH
NIOSH	National Institute for Occupational Safety and
Health RWL	Recommended Weight Limit
LI	Lifting Index4/21/2024

1. OVERVIEW

1.1 Identification of the need

1.1.1. Background

The significance of suitable ergonomic solutions is emphasized by the fact that work-related musculoskeletal diseases (WMSDs) continue to be a serious concern in many different industries. In particular, manual lifting operations provide a serious risk to employees if not properly inspected and performed. An efficient method for evaluating and enhancing the ergonomics of manual lifting activities is the NIOSH Recommended Weight Limit (NIOSH RWL) methodology. On the other hand, problems have arisen from the traditional manual application of the NIOSH RWL technique, leading to the development of a sophisticated and intuitive substitute.

1.1.2. Difficulties with Manual NIOSH RWL Application

Since the NIOSH RWL is currently applied manually, there is a risk of error due to the intricate equations involved. The manual approach's educational usefulness is restricted due to its time-consuming nature, which prevents it from being as efficient as necessary for a thorough investigation. Ergonomic improvements can be difficult to document and analyze due to the manual process's inability to generate comprehensive reports.

1.1.3. Educational Context

The learning process in the framework of the INE2012 Work Study and Ergonomics classes has a great deal of room for improvement. Using a more technologically sophisticated and intuitive approach to NIOSH RWL analysis aligns with the demands of a contemporary curriculum. The current state of education demands that a tool be created that actively displays knowledge about task parameters, risk levels, and possible ergonomic changes, while also making the NIOSH RWL approach easier to execute.

1.1.4. The Case for C-NIOSH-RWL

The C-NIOSH-RWL method was created to tackle the problems associated with applying the NIOSH Recommended Weight Limit manually. In response to the limitations of the manual method, this software offers an intuitive user interface that streamlines challenging computations. It serves as a helpful teaching tool as well, offering insightful information on the intricacies of ergonomic analysis.

1.1.5. Work Study and Ergonomics Classes Integration

The goal of enhancing students' educational experiences is the driving force behind the proposed integration of the C-NIOSH-RWL system into INE2012 classes. With the ease with which this software can be integrated into the curriculum, students will not only gain hands-on experience in ergonomic analysis, but they will also be prepared for the evolving demands of industry professionals who need proficiency with new technological tools.

In summary, the difficulties posed by the manual application of the NIOSH RWL technique led to the determination that the C-NIOSH-RWL system is required. Through the educational framework of the INE2012 Work Study and Ergonomics programs, this effort aims to close the gap between theoretical knowledge and practical application, giving students a deeper understanding of ergonomic ideas.

1.2. Definition of the problem

NIOSH RWL Application Manual Limitations

One of the biggest challenges is the current reliance on manual processes to apply the NIOSH Recommended Weight Limit (RWL). assessing the RWL, interpreting Load Index (LI) statistics, manually computing multiplier values, and assessing physiological and biomechanical aspects are some of the potential complications. Not only do these errors jeopardize the accuracy of ergonomic assessments, but they also fuel inconsistencies within the assessor pool.

Additionally, because working settings vary widely in terms of jobs, environments, and individual characteristics among workers, RWL estimations may not always suit the bill. In many industrial settings, tasks and conditions change often, making it difficult to consistently apply a static RWL to many scenarios. Furthermore, It takes knowledge and ongoing education to properly train staff to understand and comprehend RWL principles, and these resources aren't always easily accessible.

Lack of User-Friendly Tools for Education

Teaching and comprehending ergonomic concepts is made more difficult by the absence of a specialized software program. There is currently a lack of an accessible platform that enables students to input task parameters, see the relevant variables, and understand the meaning of LI values. This equipment is not user-friendly, which makes it difficult to provide instructional material efficiently and reduces the effectiveness of work study and ergonomics programs.

Inadequate documentation and analysis

The NIOSH RWL application manual technique is inadequate for generating comprehensive documentation and an ergonomic assessment analysis. The iterative nature of ergonomic adjustments makes progress difficult to monitor due to the lack of a straightforward reporting system. This deficiency poses a serious obstacle to sustaining an ongoing cycle of learning and development in the educational environment.

Industry Requirement for Technologically Qualified Graduates

Graduates with practical skills in applying ergonomic approaches using modern technologies are highly sought after in a work climate that is always evolving. The current manual approach to NIOSH RWL does not satisfy software tool competency industry standards. This mismatch highlights the need for an inventive solution like the C-NIOSH-RWL system since it causes a gap between industrial expectations and academic preparation.

The Need for a Practical and Educational Solution

Noted is a basic issue of the need for an instructive and useful solution that enhances students' learning process while removing the constraints of manual NIOSH RWL implementation. By providing a user-friendly, automated platform that complies with industry standards, modern ergonomic practices, and enhances students' comprehensive understanding of ergonomic principles, the C-NIOSH-RWL system aims to close this gap.

The limitations of manual NIOSH RWL application, the dearth of easily navigable instructional materials, the paucity of documentation, and the widening discrepancy between academic training and industry standards, to put it briefly, characterize the issue. By offering a comprehensive and cutting-edge technical solution to improve ergonomic analysis education, the C-NIOSH-RWL system seeks to address these issues.

1.2.1 Functional requirements

The Computerized NIOSH Recommended Weight Limit (C-NIOSH-RWL) system was developed in response to the challenges associated with applying the NIOSH Recommended Weight Limit (RWL) method manually. The following functional criteria list the problems that need to be fixed:

- Authentication of Users

Students must first log in using their course code and department number in order to access the C-NIOSH-RWL system.

- Administrator Authorization:

There are challenges in overseeing manual NIOSH RWL evaluations for the the manager, who has the power to control all operations and HTTP requests.

- Integration of Educational Videos:

Students are unable to easily enter work specifications due to the lack of an intuitive platform. The C-NIOSH-RWL program has an instructional video and an intuitive user interface implemented.

- Automated Calculation:

Completing calculations by hand makes it more difficult to calculate multiplier values, determine RWL, and interpret data from the Load Index (LI).The C-NIOSH-RWL system should automate these calculations for efficiency and accuracy.

- Result Presentation:

Following calculations, the risk score's numerical value and the related risk assessment need to be shown by the system.

1.2.2 Performance requirements

- System Efficiency: The system has ten seconds to complete its duties.
- It should only take ten seconds or less for a page to load.
- It must show the C-NIOSH-RWL score in less than ten seconds.

1.2.2.1 Nonfunctional Requirements

- Calculation precision:

The system must properly calculate the C-NIOSH-RWL according to the entered data.

- User Interface (UI):

Good user experience should guide the development of the C-NIOSH-RWL system. It should be user-friendly for employees and students with different levels of technological competency; thus, the system needs an easy-to-use platform to enter work settings

- Video Inclusion:

There is not enough video-based observation available to workers when using NIOSH RWL manually. The system ought to include video observation, wherein users watch a movie through the interface and then submit evaluations based on what they see.

1.2.3 Constraints

- Project Deadline:

The deadline for completing the fall semester project is December 29.

- Service Offerings:

The system will only be able to perform C-NIOSH-RWL computations and play instructional movies on the subject.

- Confidentiality of Data:

Strong encryption techniques will be used to safeguard sensitive data during transmission and storage in order to ensure confidentiality inside the system, especially when dealing with sensitive data connected to NIOSH Recommended Weight Limit (RWL) computations.

- Technology and Language:

The language of the system will be English.

Java, HTML, CSS, Javascript, Rest Api, Postman, Git, Github

- Impact on the Economy, Environment, and Society :

The C-NIOSH-RWL system's possible effects on the economy, environment, and society must be carefully considered during development and implementation. Numerous issues, such as the following, may be impacted by the complex nature of technological advancements and ergonomic solutions:

1) Economic Implications:

    - Cost-Efficiency:

The automated nature of C-NIOSH-RWL computations may lead to cost savings by reducing the time and resources typically used for calculations by humans.

    - Employee Productivity:

By enabling a more effective process in ergonomic assessments, the method may enable increased staff productivity while also aligning with financial goals.

2) Social Impact:

Enhanced Learning Experience: The approach may help increase employee productivity by facilitating an ergonomic evaluation procedure that is more efficient and aligned with financial goals. Technical Literacy: By utilizing industry-standard languages and emerging technologies, the system enhances students' technical literacy and equips them for a workforce that is heavily reliant on technology.

3) Workplace Health and Safety:

In manual lifting occupations, ergonomics and risk assessment are given a lot of weight in an effort to improve worker health and safety, which benefits society as a whole.

In summary, the development and execution of the C-NIOSH-RWL system not only fulfill project requirements, but also hold promise for positive social movements, environmental sustainability, and economic gains in both academic and professional domains.

1.3. Conceptual solutions

Automated Calculations and Visualization

Problem: Manual Limitations in NIOSH RWL Application

Conceptual Solution:

- Provide an easy-to-use interface so users may enter task parameters with ease.
- Create algorithms for the C-NIOSH-RWL system to automate the determination of LI, RWL, and multiplier values.
- Make task parameters visually clear to improve user comprehension.
- To inform users of possible ergonomic risks or updates, put in place a notification system.

With these changes, the C-NIOSH-RWL system ought to function more effectively, ensure computation accuracy, enhance user comprehension, provide historical context, and use emerging technologies.

Educational Interface and Video Integration

Problem: Lack of User-Friendly Tools for Education

Conceptual Solution:

- Design an interactive teaching module that is integrated into the C-NIOSH-RWL system.
- Include educational movies that describe the principles and functions of NIOSH RWL.
- Provide an interface, such as practical exercises that enable users to put what they've

learned into practice, that supports active learning and helps students apply concepts.

- Provide a knowledge base that can be searched so that users may easily find more resources and information.

The overall learning experience, participation of users, and educational value of the C-NIOSH-RWL system is expected to be improved by these modifications.

Comprehensive Documentation and Reporting

Problem: Inadequate Documentation and Analysis

Conceptual Solution:

- Create a reporting function in the C-NIOSH-RWL system to produce thorough reports.
- For simpler understanding and include graphic representations of the evaluation outcomes.
- Build a system to track progress and make iterative changes by storing previous information.
- Provide useful information and suggestions together with contextual understandings of the reports.
- Look at alternatives for customization that allow users to change report formats to meet specific requirements of the organization.

With these improvements, the C-NIOSH-RWL system will now provide perceptive analysis, full documentation, and customizable reporting alternatives.

Industry-Relevant Technological Proficiency

Problem: Employers Want Graduates Who Can Use Technology

Conceptual Solution:

- Include components that will help students become better acquainted with technology and fulfill the expectations of today's job.
- Provide real-world scenarios and examples into the system to fill the knowledge gap between academic training and the unique technological needs of the industry.
- Give the system interactive learning modules so that students may actively engage with and apply abstract concepts in practical settings.
- Provide a feedback mechanism that allows students to observe how they did in

hypothetical real-world scenarios, supporting ongoing enhancement and analysis.

-

Through increased opportunities for self-evaluation and interactive learning, these additional improvements intend to improve students' knowledge of technology throughout the C-NIOSH-RWL system.

Seamless User Experience and Performance Optimization

Problem: Lack of User-Friendly Tools for Education, (Performance Requirements)

Conceptual Solution:

- Optimize the C-NIOSH-RWL system to guarantee quick page loads.
- In order to guarantee continuous interaction, give top priority to creating a user interface that is clear and responsive, taking into account a variety of technological ability between users.
- Carefully evaluate the system's usability in order to collect user feedback and make appropriate interface changes to meet user expectations and improve the user experience overall.
- You can ensure optimal performance, make proactive modifications, and monitor system responsiveness over time by incorporating performance monitoring tools.
-

For long-term effectiveness, these improvements consider accessibility and ongoing evaluation of performance in addition to improving system functionality and performance.

Data Security and Confidentiality

Problem: Constraints - Data Confidentiality

Conceptual Solution:

- Put strong security measures in place to protect user information and keep it private.
- Verify respect to regulations and standards concerning data protection.
- Be cautious by keeping security protocols current to address emerging risks, steering clear of potential weak points, and ensuring ongoing data protection.
- Integrate learning tools or materials into the system for educating users on how to maintain data security and to create a shared responsibility for privacy.

In addition to protecting user privacy and data, these improvements aim to provide users with knowledge about security best practices and give them an effective reaction plan in the event of a security threat.

In the end, these theoretical solutions are designed to solve the identified problems and requirements by proposing special features and functionalities for the C-NIOSH-RWL platform. The primary goal is to increase the system's effectiveness, user-friendliness, and educational impact while ensuring that it complies with industry standards and placing a high value on reliable data security measures.

1.3.1 Literature Review

Nowadays, people try to relieve the stress of their workload by having a certain level of comfort throughout their lives, both in the workplace and in their residential areas. People are exposed to various loads both in office environments and in work environments that require physical work. Ergonomics science focuses on arranging the working environment and equipment to eliminate these burdens on employees. Arranging the working environment to ensure worker-machine harmony protects worker health and increases work efficiency. Therefore, ergonomic regulations contribute to both the worker and the employer.

[1] In this context, we can say that one of the factors affecting productivity is ergonomics, in other words, factors related to the harmony between the employee and the working environment. [10] Numerous studies have been conducted throughout the years in order to determine various methods to train workers and to evaluate their physical ability regarding the given job specification. These studies have been executed to design and redesign jobs to minimize the risk of injuries occurring from manual material handling (MMH).

[2] NIOSH is an organization that was established to ensure that employees work in safe and healthy conditions and carries out studies to improve working environments and conditions by providing training to employees and employers in the field of occupational health and safety, based on developing technology and advancing science. [3] The National Institute for Occupational Safety and Health (NIOSH) developed the Work Practices Guide for Manual Lifting in 1981 to assist safety and health practitioners in evaluating lifting and lowering jobs in the sagittal plane. The 1991 lifting equation reflects new findings, provides procedures for evaluating asymmetrical lifting jobs and objects with different types of hand-container couplings, and offers new procedures for evaluating a large range of work durations and lifting frequencies. The objective is to prevent or reduce the occurrence of lifting and lowering overexertion injuries and lower back pain among workers. [11] NIOSH application by occupational ergonomists to evaluate lifting tasks (Dempsey et al., 2018, 2005). The revised NIOSH Lifting Equation (RNLE) is applied worldwide and cited in numerous

standards, specs, and guidelines created by various enterprises, associations, and standards-making institutions such as the ISO STANDARD 11228 Part I: Manual Lifting and Carrying (ISO, 2003). With all the given validations and updates NIOSH Lifting Equations (1981) is considered succeeded by revised NIOSH Lifting Equations (RNLE). Terms for the weight limit in original NIOSH "Maximum Permissible Limit" and "Action Level" were replaced by "Recommended Weight Limit" (RWL) in the revised version of NIOSH. As an addition to horizontal and vertical location, distance in travel, frequency of lift and lifting work duration two more task variables were introduced: trunk asymmetry and hand coupling.

[3] The 1991 lifting equation is only applicable to analyzing two-handed lifting and lowering jobs, assumes that other manual handling activities are minimal and do not require significant energy expenditure, does not include unpredicted conditions such as unexpected heavy loads, slips, or falls, does not apply to tasks involving lifting while seated or kneeling, or lifting in restricted work space, does not apply to high-speed lifting or lifting unstable loads, assumes that the work environment provides a firm footing, does not account for added environmental stresses such as high temperatures and/or humidity, and assumes that lifting and lowering tasks have the same level of risk for overexertion and low back injuries. [11] LI (Lifting Index) should be utilized as a measure of the level of exposure to general physical demands for repeated manual lifting activities. The hazard information associated with different levels of the LI and suggested actions are shown in the table below which are according to the manufactured information on the association between the LI metrics LBH outcomes. The information in the table below are also included in the Annex H of the draft of the revised ISO 11228-1 (ISO, 2018).

The health and safety of employees is critical for businesses to operate effectively. Failure to apply ergonomic principles results in workstations, equipment, machines, and tools being designed often ignoring workers' differences. This may make the adaptation process of employees difficult. The importance given to health and safety in the workplace is not only a moral and legal responsibility, but it also has a great impact on organizational and individual success.

The engineer responsible for organizing the workplace and workflow can make limit value calculations according to the method closest to his/her conditions among the available methods. However, it should always be taken into consideration that the results obtained here are not exact mathematical results, and that individual and inter-individual performance differences should always be taken into consideration. It is necessary to benefit from these methods, especially in determining the level of workload, comparing the performance of workers with each other, and foreseeing and preventing excessive strain that will cause health problems [4].

The first step to prevent health problems in the industry should be to identify the factors that cause health problems. Ergonomists have acknowledged the very protectionist nature of the revised NIOSH lifting equation when using it to evaluate professional lifting tasks. For this purpose, the NIOSH Lifting Equal is a tool that occupational physicians can easily use [5].

Employee motivation, work abilities and productivity increase by providing good ergonomic conditions. Ergonomic risk factors can lead to Musculoskeletal Disorders (MSDs), which are associated with factors such as repetitive work, continuous work, and poor postures. Ergonomics is an important factor in industry and plays a particularly influential role in the efficiency of companies. Complaints arising from employees' body postures are common due to non-ergonomic work environments and incomplete information.

It is stated that workplace types vary depending on sectoral differences and these differences affect risks. For example, it is stated that workplaces in the manufacturing industry usually have machines, equipment, and material handlers, while employees in the service sector interact with customers and use tools such as computers and phones [6]. This situation reveals the differences in risks specific to sectors. For example, waist and back pain, pain in hand and arm joints, and headaches frequently encountered by computer users differ from the effects of long working hours, standing position, repetitive motion, and a stressful work environment for restaurant workers [7,8].

Donisi et al. (2021), in their study titled "Work-Related Risk Assessment According to the Revised NIOSH Lifting Equation: A Preliminary Study Using a Wearable Inertial Sensor and Machine Learning", aimed to examine the use of wearable inertial sensors and machine learning in work-related risk assessments. In this study, the risk of work-related back disorders was evaluated using the Revised National Institute of Occupational Safety and Health (NIOSH) Lifting Equation (RNLE) risk classes by extracting features from the acceleration and angular velocity information obtained with an inertial measurement unit (IMU) placed in the pelvic area. A commercial IMU-based wearable device called Opal System was used to collect raw data during lifts. The primary objective of the study is to evaluate biomechanical risk with the usability of a single IMU and classify lifting tasks based on RNLE risk classes.

The results showed that the tree-based algorithms had more than 90% accuracy and area under the Receiver Operator Characteristic (ROC) curve (AUC) values higher than 0.9. Donisi et al (2021) provide suggestions for practical applications of this study, particularly ergonomic assessments and worker safety measures. Integration of wearable IMU technology and machine learning algorithms reveals a new and effective approach to measuring and classifying biomechanical risks during manual lifting tasks. It is suggested that future studies could focus on larger participant groups and advanced machine learning algorithms to improve system accuracy [9].

In future studies, it is recommended to conduct more detailed analyzes on determining ergonomic risks separately by sector and classifying these risks according to various factors. The NIOSH lifting equation is a method used to analyze ergonomic risks, especially in work environments where lifting and carrying tasks are performed. In this way, areas that need improvement can be identified and the burdens that employees are exposed to can be reduced.

Another study investigates musculoskeletal disorders and manual lifting among male industrial workers in Shiraz, Iran, and highlights the prevalence of back problems. Using both the NIOSH lifting equation and the WISHA index and comparing these methods, the study finds that 79.2% of subjects evaluated using the NIOSH equation were at risk for back injury. In comparison, the WISHA index shows that 60.8% of participants lifted loads lighter than the acceptable weight, and a fair correlation (Kappa coefficient 0.29) was observed between the two evaluation methods. The study suggests that despite the comprehensive and possibly more reliable results produced by the NIOSH lifting equation, the WISHA index, with its understandability and shortened evaluation time, is more suitable for evaluating manual lifting activities in Iranian industries. Considering that the research was limited to male industrial workers, caution is advised when trying to generalize the findings to female workers. The moderate correlation between the two methods supports the recommendation for the pragmatic use of the more unsophisticated WISHA index in Iranian industries [13].

Numerous studies have highlighted limitations in both the original and revised versions of the NIOSH equation, pointing to tasks exceeding recommended weight limits and necessitating redesign. **Table 1** indicates a consistent linear decrease of 9.6% in MAWL (Maximum Acceptable Weight of Lift) through the NIOSH lifting equation, whereas the six studies show a non-linear average reduction. Specifically, the MAWL reduces by 8.8% and 5.1% with angle changes from 30 to 60 degrees and from 60 to 90 degrees, respectively. These findings emphasize the necessity of re-evaluating the structure of the asymmetric multiplier, as recommended by NIOSH guidelines. Elfeituri and Taboun (1999) summarized past psychophysical and biomechanical experiments to assess NIOSH lifting guidelines. The analysis highlights that real-world lifting conditions are often different from NIOSH guidelines, especially regarding horizontal shifts, vertical distances, and lifting frequency. The study shows that factors like a 45 cm horizontal shift significantly reduce loads, challenging NIOSH's 25 cm limit as unrealistic. Another important factor is lifting frequency, where larger frequencies result in significantly lower loads. This implies that depending only on NIOSH guidelines may not be feasible and highlights the necessity for data that takes into account realistic task characteristics. Research indicates that disk compression frequently surpasses the 3400 N limit, with an average value of 2.5 to 8.0 kN. Peak forces in biomechanical experiments increased to 3685.4 N, more than half of which exceeded the NIOSH limit. Interestingly, in psychophysical trials, participants altered loads based on their experience of physical stress, so despite these high values, postural limits did not significantly put risk on participants' spine [12].

TABLE 1. Reduction in the Maximum Acceptable Weight of Lift (MAWL) Due to Asymmetry

	Angle of Asymmetry (°)		
Source	**30**	**60**	**90**
Average of six studies	11.0%	19.8%	24.9%
NIOSH lifting equation	9.6%	19.2%	28.8%

Table 1

[12]

Table 2
Interpretation of Lifting Index and derivates (*LI, CLI, VLI, SLI*).

Lifting Index Value (Exposure level)	Risk Implication	Recommended Actions
LI ≤ 1,0	Very low	None in general for the healthy working population.
1,0 < LI ≤ 1,5	Low	In particular pay attention to low frequency/high load conditions and to extreme or static postures. Include all factors in redesigning tasks or workstations and consider efforts to lower the LI to values ≤ 1,0.
1,5 < LI ≤ 2,0	Moderate	Redesign tasks and workplaces according to priorities to reduce the LI, followed by analysis of results to confirm effectiveness.
2,0 < LI ≤ 3,0	High	Changes to the task to reduce the LI should be a high priority.
LI > 3,0	Very high	Changes to the task to reduce the LI should be made immediately.
For Any level of Risk/Exposure	Identify any workers who may have special needs or vulnerabilities in lifting tasks and assign or design the work accordingly. Training workers on recognizing and eliminating material handling hazards is regarded as beneficial. Limiting the weight to be lifted, to less than the Reference Mass may also be considered.	

Table 2

[11]

1.3.2. Concepts: Object-Oriented Programming Language Comparison

Objective:

The goal of the language comparison was to determine which technology stack would be best for developing the C-NIOSH-RWL system. The comparison took into account important elements that matched the selected technologies, including cost, complexity, performance, and features.

Decision:

HTML, CSS, JavaScript, and Spring were found to be the most appropriate technologies for the C-NIOSH-RWL system development, considering the current technological stack.

Cost: Since HTML, CSS, JavaScript, and Spring are all open-source and often used, they are inexpensive for the project as a whole.

Complexity: The mix of JavaScript, HTML, CSS, and Spring results in a medium degree of complexity. JavaScript handles client-side interactivity, HTML and CSS handle the display layer, and Spring helps with server-side logic. This makes it possible to use a modular and well-organized development process.

Performance: JavaScript handles client-side interactions, and Spring has strong server-side capabilities. The performance is deemed medium. This is appropriate given the project's educational setting.

Features: There are a lot of features available in the selected stack. Together, JavaScript for interactivity, HTML for content organization, CSS for style, and Spring for server-side functionality offer a powerful toolbox for creating feature-rich applications.

Educational Focus: Because the selected stack contains widely used web development technologies, it is in good alignment with the learning objectives.

Integration: Because Spring is a Java-based framework, it easily interfaces with JavaScript, HTML, and CSS, enabling a unified development approach.

Conclusion:

With respect to the current technological stack and its compliance with the project specifications, the selection of HTML, CSS, JavaScript, and Spring is sound. This combination offers a well-rounded strategy that makes use of the advantages of each technology to successfully construct the C-NIOSH-RWL system.

Concept	Cost	Complexity	Performance
HTML	Low	Medium	High
CSS	Low	Low	Medium
JavaScript	Low	Medium	Medium
Spring	Medium	High	High
Wireframe	Medium	Medium	Medium

Table 3: Object-Oriented Programming Language Comparison

1.4. Physical architecture

User Interface (UI) Layer:

Input Interface: This layer consists of the input elements where users may enter the parameters for the job. It consists of fields and forms for collecting data on things like weight, height at which objects are lifted, frequency of lifting, etc. In this area, users may additionally give the analysis an ID.

Visualization Interface: This section shows the task's parameters graphically and provides an understandable explanation of each one (e.g., graphical representations for the horizontal multiplier). Result Display Interface: The estimated multiplier values, RWL value, load index (LI) value, risk level interpretation, and suggested ergonomic improvements are all displayed on the result display interface. For instructional reasons, the result is provided in an understandable way.

Report Generation Interface: Users may create reports that provide a summary of all the data they were able to get from the analysis. The report must be simple to download and print, ideally in PDF format.

Business Logic Layer:

Parameter Processing Module: This module checks the accuracy and completeness of the job parameters entered.

Calculation Module: In charge of determining multiplier values, RWL, and LI as well as carrying out computations depending on the parameters entered.

Interpretation Module: This module evaluates the task's level of risk and interprets the LI value. Based on the data, it recommends ergonomic adjustments as well.

Reporting Module: Produces an extensive report with all the computed values, explanations, and recommended enhancements.

Presentation Layer:

Web-Based Interface: This layer manages how the user interface is shown to users via a web browser if the system is designed as a web application.

Communication Layer:

Communication Protocols: Make sure that the system's various levels and modules can communicate with one another.

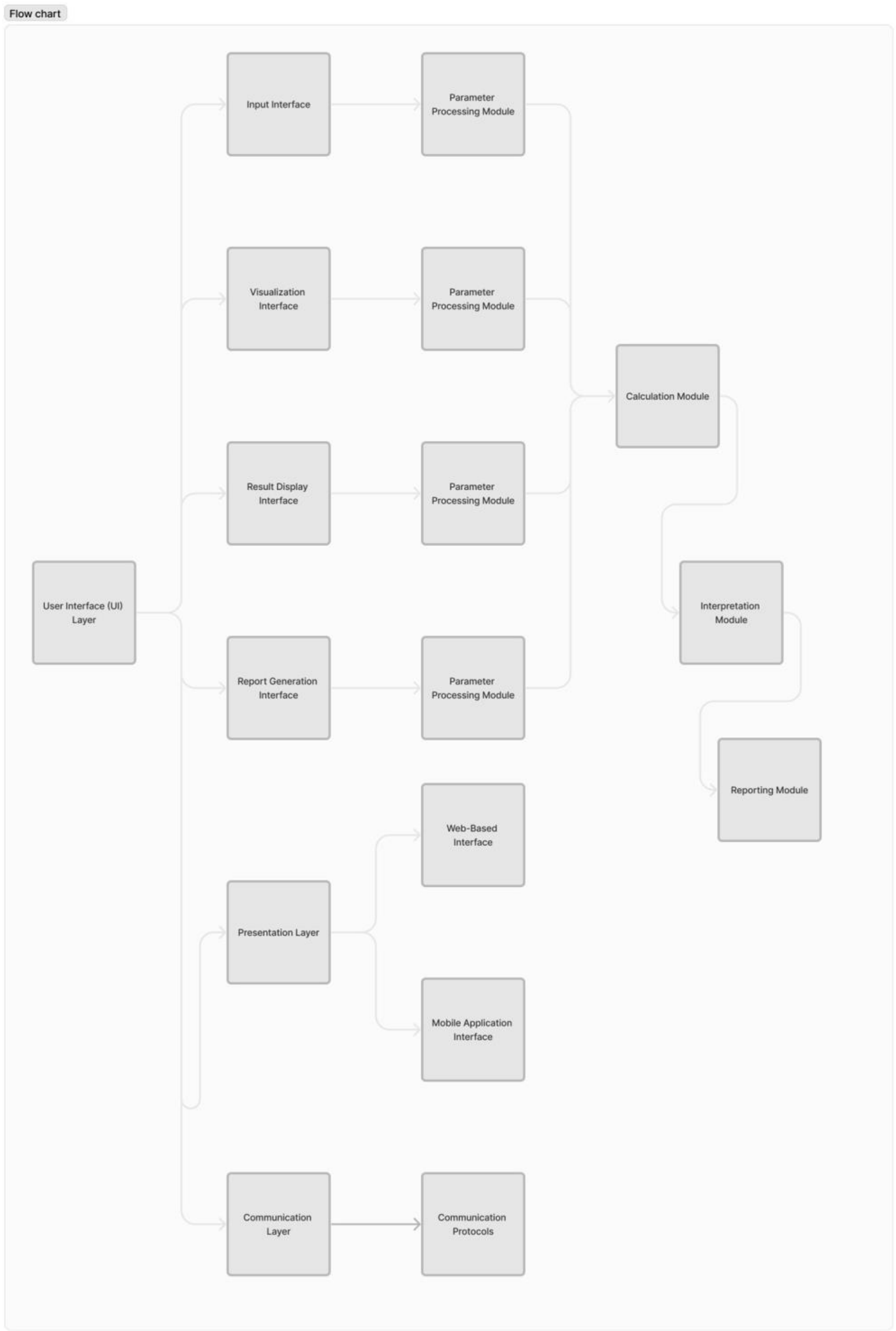

Figure 1: Flow Chart

2. WORK PLAN

2.1. Work Breakdown Structure (WBS)

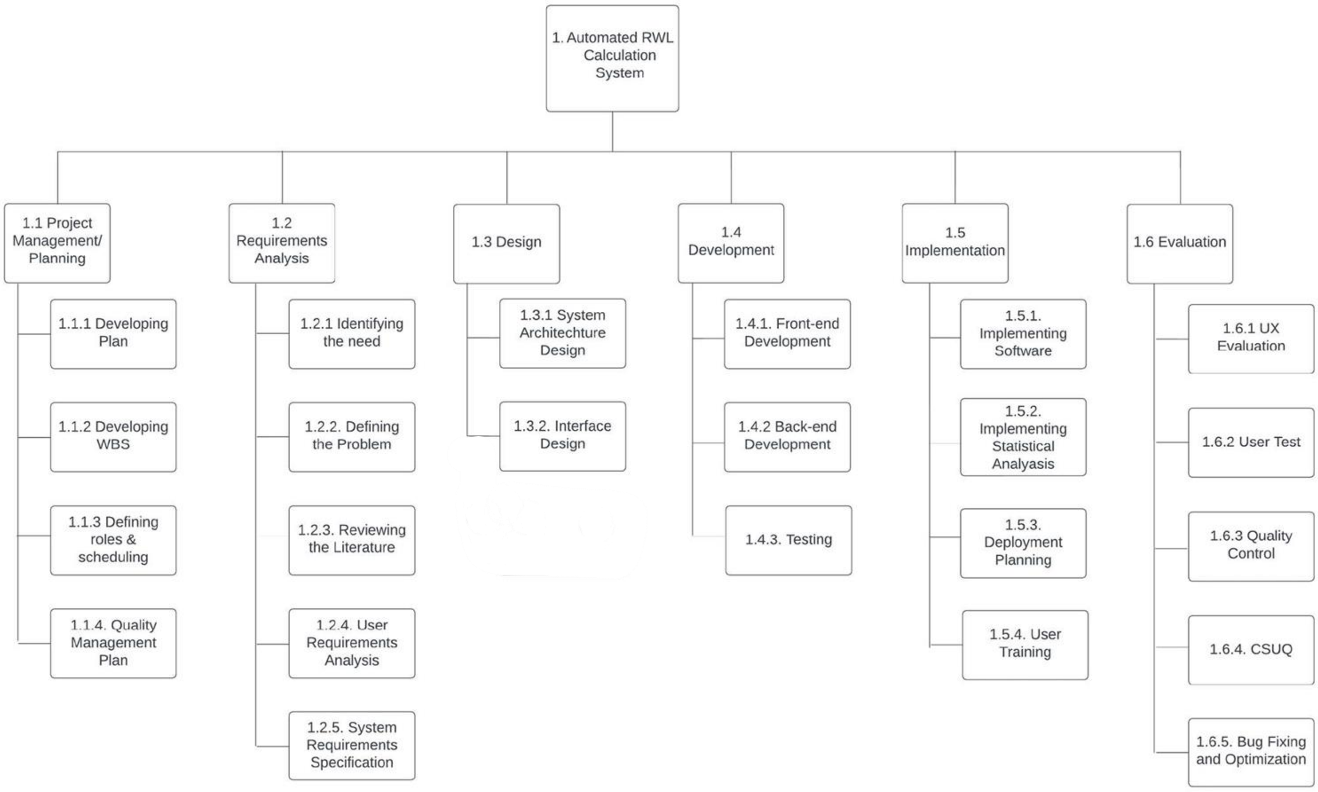

Figure 2: Work breakdown structure for the project

2.2. Responsibility Matrix (RM)

TASK	BAŞAK	ÜMMÜ	HERMANN	YİĞİT	ZEYNEP	ÇAĞLA
Project planning	R	R	R	R	R	R
Requirement analysis	S	R	R	R	S	S
Conceptualization	R	R	R	S	S	S
Definition of Technologies and methods	R	R	R	R	S	S
UX design	S	S	S	R	R	R
Software Design	R	R	R	S	S	S
Implementation	R	R	R	S	S	S
Data collection	S	S	S	R	R	R
Testing	S	S	R	R	S	S
Integration	R	R	S	S	S	S
Evaluation	R	S	R	R	R	R
Conclusion	S	R	R	R	R	R
Report	R	R	S	S	S	R

R= Responsibility

S= Support

Figure 3: Responsibility matrix for the project

2.3. Project Network (PN)

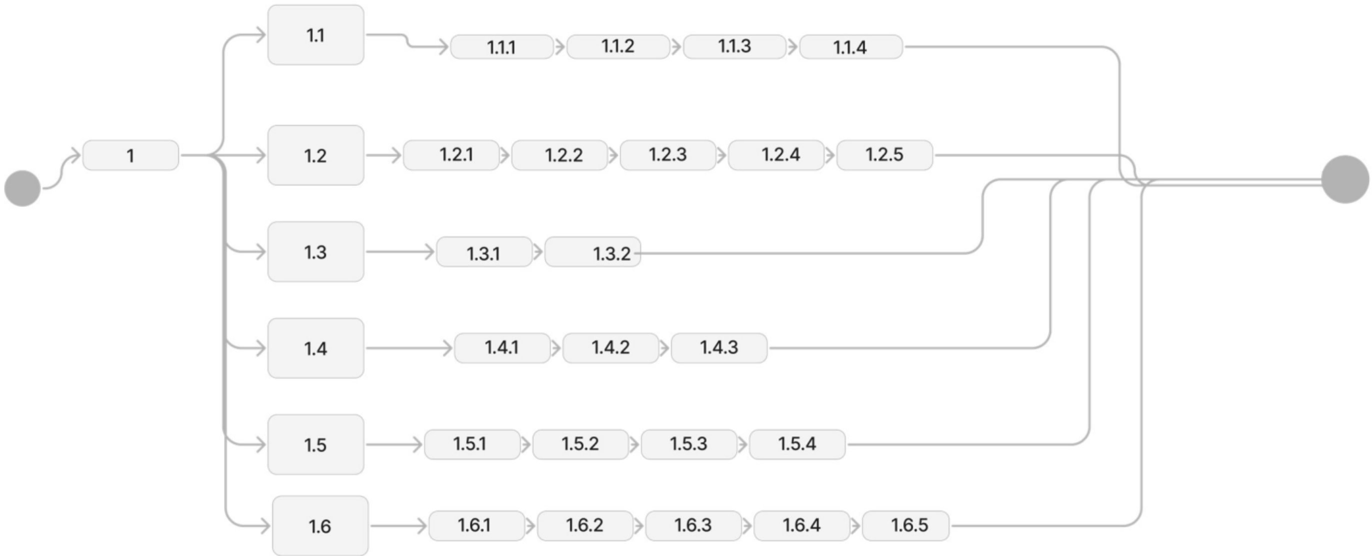

Figure 4: Project Network

2.4. Gantt chart

Figure 5: Gantt Chart

2.5. Costs

Open Source Framework: One open-source framework is Java Spring. It can therefore be used, altered, and distributed without any financial burden by anybody. Java Spring may be used for non-commercial or educational purposes without incurring any licensing obligations.

help from the

Community: Java Spring offers a sizable and dynamic developer community that uses forums, online communities, and documentation to share expertise, contribute to the project's development, and offer help. All users, including educational institutions and non-commercial initiatives, get free access to this community support.

No other Software Fees: Java Spring is a framework for developing Java apps, therefore using it doesn't need purchasing any other software licenses or subscriptions. You can begin creating Java Spring applications for free as long as you have installed the Java Development Kit (JDK), which is also accessible.

Host: We temporarily used Amazon Web Services (AWS) because we haven't invested any money in the project and haven't bought a domain yet.

2.6. Risk analysis

A key element of project risk management is the risk definition table, which ranks possible hazards according to their probability of happening and the seriousness of their effects. It helps project managers determine which hazards need to be planned for and addressed right away. While risks that are extremely likely to occur and have large repercussions require considerable adjustments to project plans in order to limit their impact, small risks with very low chance may not require any action at all. In order to ensure the project's success, this methodical approach to risk classification helps prioritize risk mitigation activities and allocate resources wisely.

Risk Level	Minor	Moderate	Major
Unlikely	VERY LOW	LOW	MEDIUM
Possible	LOW	MEDIUM	HIGH
Likely	MEDIUM	HIGH	VERY HIGH

Table 4: Risk Matrix – 1

Very Low	This is event is very low risk and so does not require any plan for mitigation. In the unlikely event that is does occur there will be only a minor effect on the Project.
Low	This is event is low risk; a preliminary study on a plan of action to recover from the event can be performed and noted.
Medium	This event presents a significant risk; a plan of action to recover from it should be made and resources sourced in advance.
High	This event presents a very significant risk. Consider changing the product design/Project plan to reduce the risk; else a plan of action for recovery should be made and resources sourced in advance.
Very High	This is unacceptable risk. The product design/Project plan must be changed to reduce the risk on the acceptable level.

Table 5: Risk Matrix - 2

Table 6: Risk Assessment

Risk Tag	Description	Probability	Impact	Priority	Mitigation Strategies
R1	Lack of User Feedback	Low	Low	Medium	Implement regular surveys and user testing sessions to gather consistent feedback.
R2	Server Performance Issues	Low	Medium	Medium	Conduct regular performance monitoring and optimize server resources accordingly.
R3	Regulatory Changes	Low	High	Low	Stay updated with regulatory bodies, maintain flexibility in systems to adapt swiftly to changes.
R4	Inadequate Security Measures	Medium	Low	Low	Implement regular security audits and updates, employ encryption, and multifactor authentication.
R5	Compatibility Issues	Medium	Medium	Medium	Test across multiple platforms and devices to ensure seamless compatibility.

R6	Insufficient Documentation	Medium	High	High	Establish comprehensive and easily accessible documentation for all processes and systems.
R7	Data Breach	Low	Medium	Low	Implement robust encryption, regular security assessments, and response protocols.
R8	Algorithm Error	High	Medium	High	Conduct thorough testing and validation protocols to ensure algorithm accuracy and reliability.
R9	Server Outages	Low	High	Medium	Set up redundant systems and failover mechanisms to minimize downtime during server outages.

3. SUB-SYSTEMS

3.1. The name of the subsystem

Subsystem Department: Software Engineering

Sub-System Work Groups: System Integration

The team's goal is to gain a broad understanding of the system, and NIOSH RWL's coding will be done by students in the software engineering department. The department of software engineering will concentrate on putting the wireframes—the final version of the design—into practice. To guarantee a thorough approach, documentation will be created concurrently with the project preparation in conjunction with the department of industrial engineering.

The system must be easy to use and able to continue operating even when there are problems. Correction of defects and mistakes is the purview of the software engineering department.

It is anticipated that the system will provide relevant documentation and educational materials in order for users to understand the system.

Sustainability will be taken into account when the project is finished, and there may be opportunities for ongoing maintenance and improvements in conjunction with the department of industrial engineering.

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3.1.1. Requirements

By creating a useful ergonomics tool, our research seeks to provide the groundwork for Bahçeşehir University's Department of Industrial Engineering. Our goal is to develop an application that is easy to use on both web and mobile platforms so that students may use the NIOSH approach they are taught in class. The primary aim is to improve students' comprehension of the subject matter by facilitating the learning and practical implementation of the NIOSH approach through a purposeful application.

A number of functional requirements must be satisfied by the C-NIOSH-RWL system in order to properly analyse workplace ergonomics. To help with comprehension, it should mainly enable users to input task parameters and offer a visual depiction of these elements. Multiplier values, RWL values, and Load Index (LI) values are computed by the system. The associated risk level for the specific job is then determined by interpreting the LI result. In addition, the system ought to suggest ergonomic modifications and furnish a comprehensive report with all calculated figures and suggestions, as per the investigation. Together, these characteristics allow the system to offer a thorough assessment of an activity's ergonomic components.

In addition to its functional requirements, the C-NIOSH-RWL system must fulfil several non-functional criteria. In accordance with accepted UX criteria, it must prioritize a user-friendly experience in order to guarantee accessibility and ease of use. By giving users access to work parameters, RWL, LI, and related risk levels, the system aims to educate its users. Moreover, it provides findings in forms that are readily printed and savable, such PDF, facilitating seamless integration into current workflows. C-NIOSH-RWL is positioned as a comprehensive instrument for ergonomic study and improvement in a university context due to its dual emphasis on functionality and user experience.

3.1.1.1 Behaviors of the Software Application

Actor Name	Name of Behavior (Function)	Description of Behavior
System	**index()**	Returns the view name for the index page.
System	**learn()**	Returns the view name for the learn page.
System	**about()**	Returns the view name for the about page.
System	**showCalculationForm()**	Returns the view name for the calculation form page.
System	**calculate(CalculationRequest, BindingResult, Model)**	Handles the calculation request, performs calculations based on user input, and redirects to result or fail page based on the outcome.
System	**fail(double, double, double, double, double, double, CouplingType, double, Model)**	Populates the model with parameters and returns the view name for the fail page.
System	**showResult(double, double, double, double, double, double, double, double, double, double, double, double, double, CouplingType, double, Model)**	Populates the model with calculation results and returns the view name for the result page.
System	**viewPage(Model)**	Returns the view name for a general view page.
System	**downloadPDF(double, double, double, double, double, double, double, double, double, double, double, double, double, CouplingType, String, String)**	Generates a PDF based on calculation results and user inputs, and initiates the download of the PDF file.
System	**riskValue(double)**	Determines the risk value and recommended action based on the Load Index (LI) and returns an array containing these values.

Table 7: Behaviors of the Software Application

3.1.1.2 Attributes of the Software Application

Attribute	Element	Description
xmlns:th	<html>	XML namespace declaration for Thymeleaf.
charset	<meta>	Character encoding for the document (UTF-8).
name	<meta>	Metadata name attribute; in this case, "viewport" indicates how the document should be displayed on different devices.
content	<meta>	Content of the meta element; for viewport, it sets the viewport to make the website responsive.
rel	<link>	Relationship between the current document and the linked resource (stylesheet or external CSS library).
type	<link>	Type of the linked resource (text/css for stylesheets).
href	<link>	URL of the linked resource (e.g., external stylesheets and libraries).
class	Various (e.g., <nav>, <a>, <button>, <div>, ,)	CSS class attribute used for styling purposes.
id	Various (e.g., <div>, <input>, <select>, <button>)	Unique identifier for an element.
type	Various (e.g., <button>, <input>)	Type of input element (button, number, select, etc.).
data-toggle	<button>	Attribute used by Bootstrap to toggle functionality, e.g., collapsing navigation.
data-target	<button>	Attribute used by Bootstrap to specify the target element that should be toggled.
aria-controls	<button>	Defines the elements that the button controls (for accessibility).
aria-expanded	<button>	Indicates whether the element it controls is expanded or collapsed.
aria-label	<button>	Provides an accessible label for the button.
for	<label>	Associates a label with a form control.
name	Various (e.g., <input>, <select>)	Name of the form control, which is submitted with the form data.
placeholder	<input>	Placeholder text displayed in an input field when it is empty.
th:action	<form>	Thymeleaf attribute used to specify the URL to submit the form to.
method	<form>	HTTP method to use when submitting the form (GET or POST).
th:value	Various (e.g., <input>, <select>)	Thymeleaf attribute to bind form fields to model attributes.
title	<div>	Tooltip text displayed when the element is hovered over.
step	<input>	Specifies the legal number intervals for an input field.
value	<option>	The value that will be submitted if this option is selected.
src	<script>	URL of an external script to be executed.

Table 8: Attributes of the Software Application

3.1.1.3 Performance Requirements

Performance of the C-NIOSH-RWL system is essential to guaranteeing both its efficacy and user happiness. The anticipated behavior and responsiveness of the software programme are defined by the following performance requirements:

Response Time:

The system should respond to user inputs in two seconds for normal activities.

Completing intricate computations, including calculating RWL values and the load index (LI), shouldn't take more than five seconds.

Scalability:

It must be possible for the programme to support at least 50 concurrent users without noticeably degrading performance.

Scalability testing is necessary to evaluate the application's capacity to handle increasing user loads without compromising responsiveness.

Reliability and Availability:

With the exception of planned maintenance periods, the system should be accessible 99.9% of the time.

In the case of a system failure, the software ought to recuperate and start up again in ten minutes.

Compatibility:

Popular online browsers like Chrome, Firefox, and Safari as well as mobile platforms like iOS and Android must be compatible with the software.

Compatibility testing needs to be done often in order to guarantee top performance across a range of platforms and devices.

Security Performance:

Secure data communication protocols should be used by the system to safeguard user inputs and outputs.

To find and fix any vulnerabilities, regular penetration tests and security audits should be carried out.

User Interface Responsiveness:

There should be no more than three seconds between page loads and a smooth, responsive user experience.

For instance, data entry and report creation must go smoothly and without any hiccups.

Error Handling:

Errors must be handled by the programme effectively, with user-friendly error messages.

Error resolution procedures, such applying bug fixes and system upgrades, should be put into place as quickly as feasible to minimize downtime.

Resource Utilization:

To optimize system resources like CPU, memory, and storage, the software should be tweaked.

Regular performance monitoring is necessary to locate and fix resource bottlenecks.

3.1.1.4 Business Rules

The high-level goals and expectations that the C-NIOSH-RWL system has to achieve to satisfy the needs of the System Integration Work Groups and Software Engineering Department at Bahçeşehir University are outlined in the business requirements.

Strategic Alignment:

The C-NIOSH-RWL system needs to support the growth of ergonomic research in the Department of Industrial Engineering and be in line with the strategic objectives and purpose of Bahçeşehir University's Software Engineering Department.

User Engagement:

Through the provision of an intuitive user interface that encourages active participation in ergonomic studies, the system should successfully engage students.

Surveys and user reviews are examples of frequent feedback systems that should be used in order to gather insights and enhance customer satisfaction.

Educational Enhancement:

Enhancing the educational experience for students in the Department of Industrial Engineering is the main goal of the system.

Via the application of theoretical knowledge in practical settings, the programme should enable students to understand the NIOSH approach via hands-on experience.

Collaboration with Industrial Engineering:

Collaboration between the departments of Industrial Engineering and Software Engineering must be facilitated via the C-NIOSH-RWL system.

The integration of documentation and project development methods is crucial to provide a cohesive and multidisciplinary approach.

Maintenance and sustainability:

Designing the system with sustainability in mind will enable continuous maintenance and updates in collaboration with the Industrial Engineering Department.

It is important to plan ahead and execute maintenance tasks effectively to prevent interruptions in system availability.

Data Privacy and Security:

The system must adhere to all applicable data privacy and security laws and guidelines.

User data should be managed securely, and access limits should be upheld to guarantee confidentiality. This is especially true of sensitive ergonomic data.

Scalability and Future growth:

To accommodate future increases in the number of users and data volume, the programme must be scalable.

As departmental demands change, the system architecture and design should be flexible enough to include new modules and features.

Cost-Effectiveness:

To attain cost-effectiveness, the development and maintenance expenses of the C-NIOSH-RWL system should be minimized.

The system should improve ergonomic studies at the institution and meet educational objectives while providing a satisfactory return on investment.

Regulatory Compliance:

All applicable legal requirements, as well as standards for educational technology, must be met by the system.

Regular audits and reviews are necessary to guarantee ongoing adherence to evolving legal requirements.

3.1.2. Technologies and methods

Utilizing popular and widely-used technology, the next system will guarantee responsiveness and peak performance. These technologies are frequently used in the creation of responsive systems because of their demonstrated dependability.

Technology	Usage
HTML	Provides frontend structure and markup for dynamic web interfaces
CSS	Responsible for styling and layout design, enhancing user interface
JavaScript	Implements frontend scripting for interactive and dynamic web behavior
Spring Boot	Powers backend development, handling business logic
REST APIs	Facilitates communication between frontend and backend services
PDF Format	Utilized for report generation, enabling easy printing and saving

Table 9: Technologies and Methods

3.1.3. Conceptualization

3.1.3.1 Actor Glossary

Below are details for the roles of key actors within the C-RWL-NIOSH website which are User, Model, Widget.

Actor	Description
User	Person who wants to calculate the RWL value.
Model	Unit responsible for calculating the RWL value based on given input.
Widget	Unit the user interacts with. Front-end part of the system.

Table 10: Actor Glossary

3.1.3.2 Use Case Glossary

Use Case Name	Description	Participating Actor(s)
Successful Calculation	This use case involves a user successfully performing a C-RWL-NIOSH calculation, receiving a safe result, and accessing recommendations or next steps.	User, Model, Widget
Borderline Calculation	A new user performs a C-RWL-NIOSH calculation resulting in a borderline or cautionary zone outcome, receiving additional safety	New User, Model, Widget

	measures or advice.	
Exceeding Safe Limits	An experienced user calculates C-RWL-NIOSH, resulting in an unsafe condition, and receives urgent warnings and safety protocols.	Experienced User, Model, Widget

Table 11: Use Case Glossary

USE CASE #1	Description
Use-Case Name	Successful Calculation
Use-Case Description	This use case involves a user successfully performing a C-RWL-NIOSH calculation, receiving a safe result, and accessing recommendations or next steps.
Primary Actor (s)	User
Supporting Actor (s)	Model, Widget
Pre-Condition	User has access to the calculation page.
Post-Condition	User receives a "Dark Green" result and accesses recommendations or next steps.
Normal Flow	1.) User accesses the website.
	2.) Accesses the Calculation Page. 3.) User inputs data and Model performs C-RWL-NIOSH calculation. 4.) Submits calculation. 5.) Redirected to Result Page. 6.) Displays "Dark Green" result. 7.) Provides recommendations or next steps.

Table 12: Use Case #1

USE CASE #2	Description
Use-Case Name	Borderline Calculation
Use-Case Description	A new user performs a C-RWL-NIOSH calculation resulting in a borderline or cautionary zone outcome, receiving additional safety measures or advice.
Primary Actor (s)	New User
Supporting Actor (s)	Model, Widget
Pre-Condition	New user has access to the calculation page.
Post-Condition	User receives a "Light Green" or "Yellow" result and additional safety measures/advice.
Normal Flow	1.) New user enters the website. 2.) Navigates to the Calculation Page. 3.) User inputs data and Model performs C-RWL-NIOSH calculation. 4.) Displays "Light Green" or "Yellow" result. 5.) Offers additional safety measures or advice.

Table 13: Use Case #2

USE CASE #3	Description
Use-Case Name	Exceeding Safe Limits
Use-Case Description	An experienced user calculates C-RWL-NIOSH, resulting in an unsafe condition, and receives urgent warnings and safety protocols.
Primary Actor (s)	Experienced User
Supporting Actor (s)	Model, Widget
Pre-Condition	Experienced user accesses the calculation page.
Post-Condition	User receives an "Orange" or "Red" result, warnings, and safety protocols.

Normal Flow	1.) Experienced user comes back to the website. 2.) User inputs data and Model performs C- RWL-NIOSH calculation. 3.) Displays "Orange" or "Red" result. 4.) Provides urgent warnings and safety protocols.

Table 14: Use Case #3

3.1.3.3 Use Case Diagrams

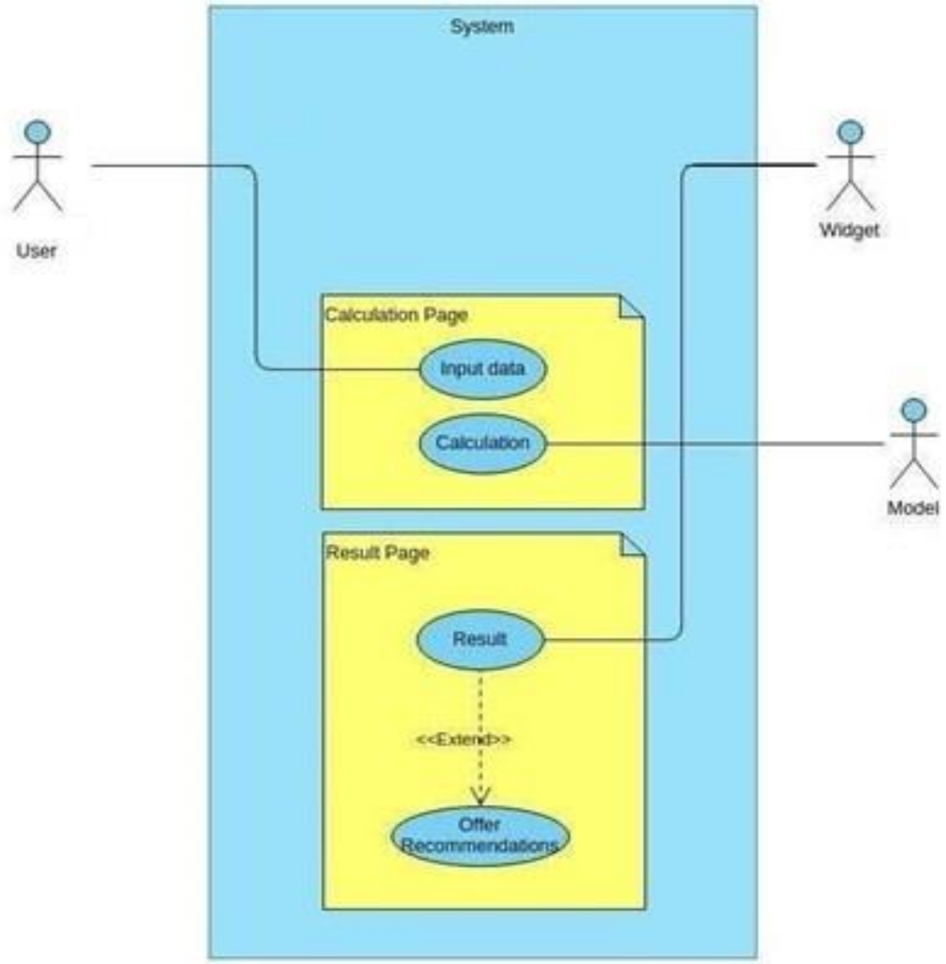


Figure 6: Use Case Diagram 1

The system's interactions with a User who successfully completes a C-RWL-NIOSH computation are depicted in this figure. The user is sent to the Result Page by the system after submitting, where a "Dark Green" result denoting safety is displayed. In order to guarantee a flawless user experience, the system then offers suggestions or next actions.

The interactions between the system and a new user during a C-RWL-NIOSH computation that produced a borderline or cautionary zone conclusion are depicted in this diagram. Following data entry and computation, the system displays a "Light Green" or "Yellow" result, which prompts the user to comprehend and be safe by providing extra safety measures or advise.

The interactions between the system and an Experienced User carrying out a C-RWL-NIOSH computation that exceeds safe limits are depicted in this diagram. An "Orange" or "Red" result is produced when the user enter values and do the computation. The user is instantly alerted to the dangerous situation and necessary safeguards by the system through the fast delivery of urgent warnings and safety routines.

3.1.3.4 Activity Diagrams

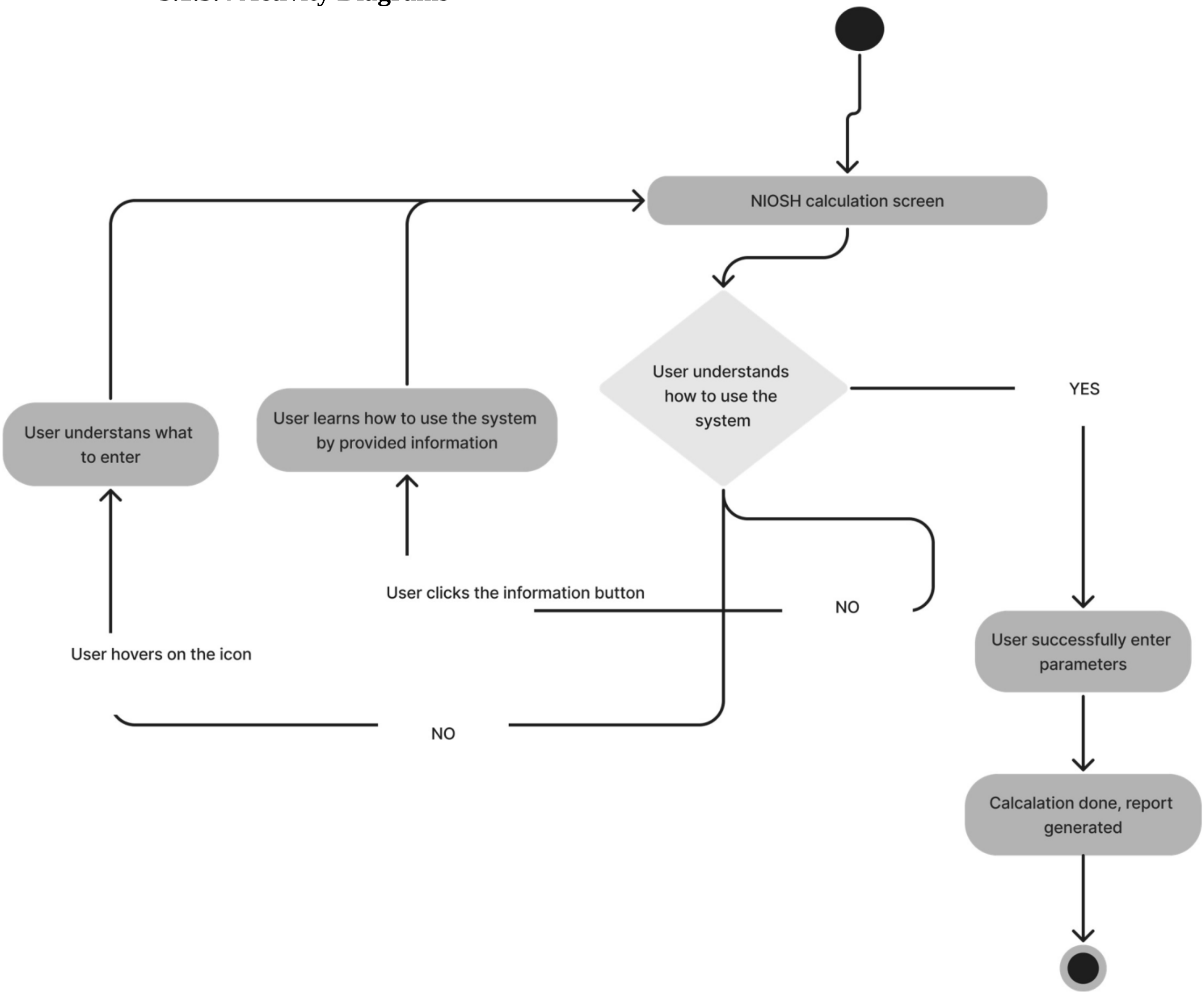


Figure 11: Activity Diagram 1

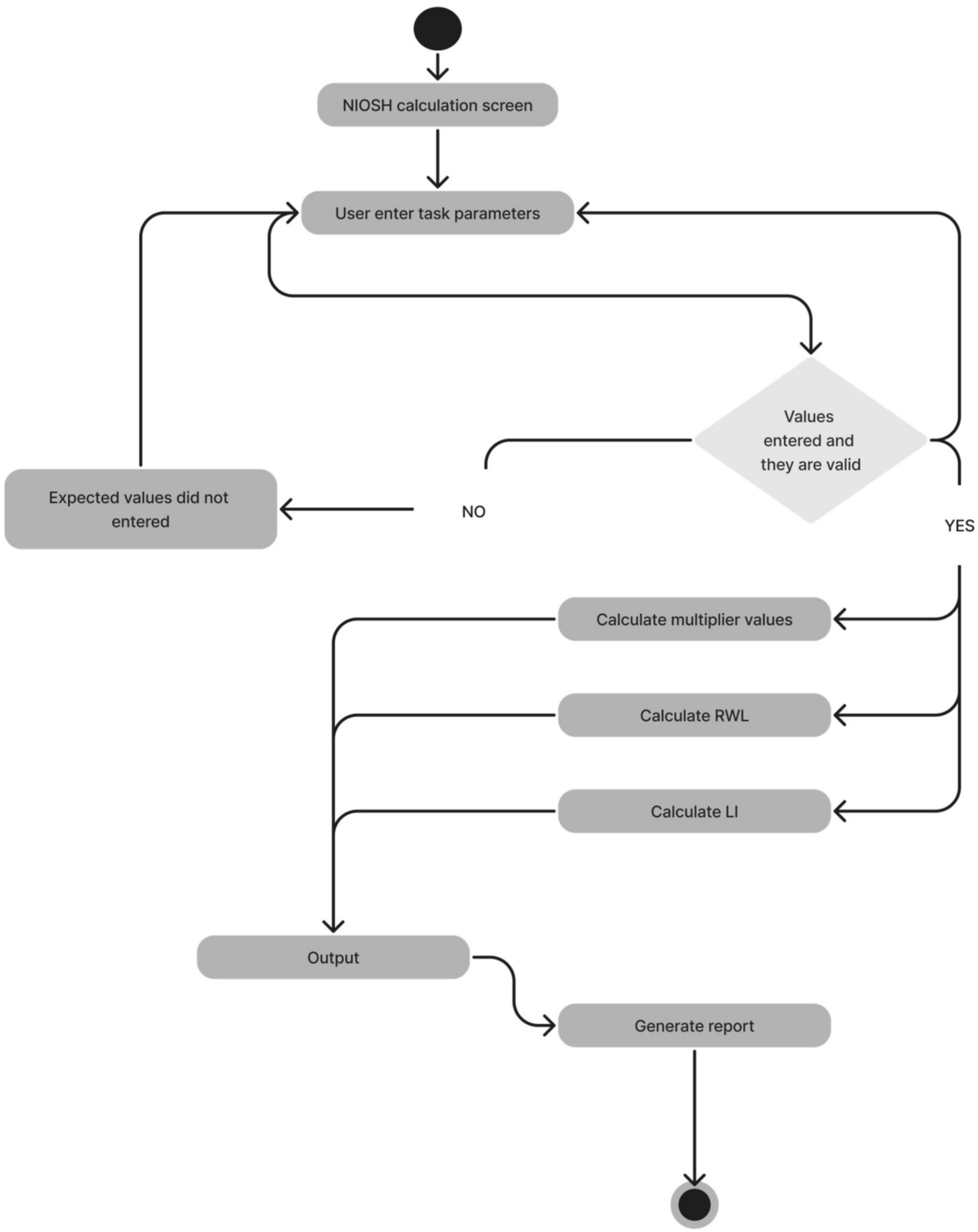


Figure 12: Activity Diagram 2

3.1.3.5 Data Flow Diagram

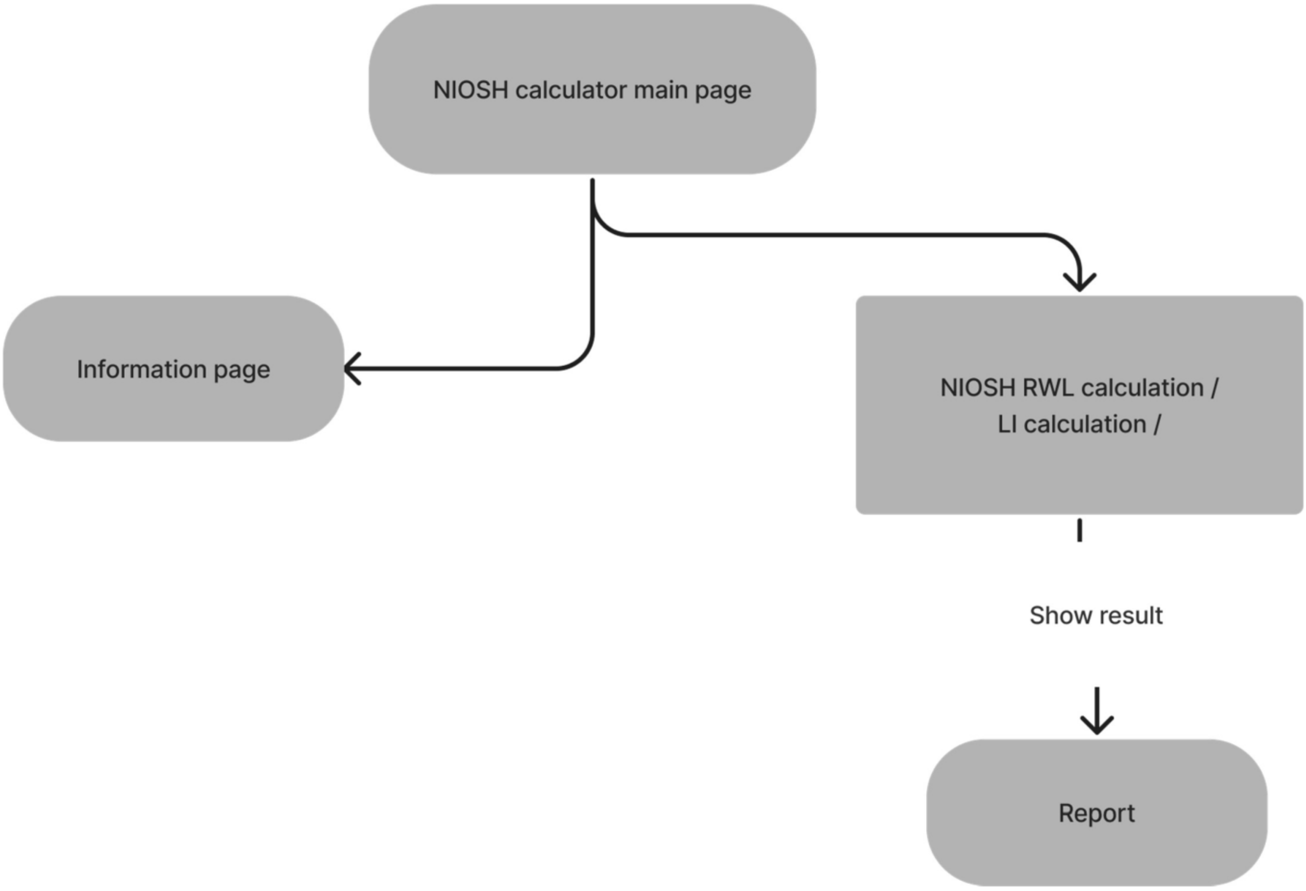


Figure 13: Data Flow Diagram

3.1.3.6 Sequence Diagrams

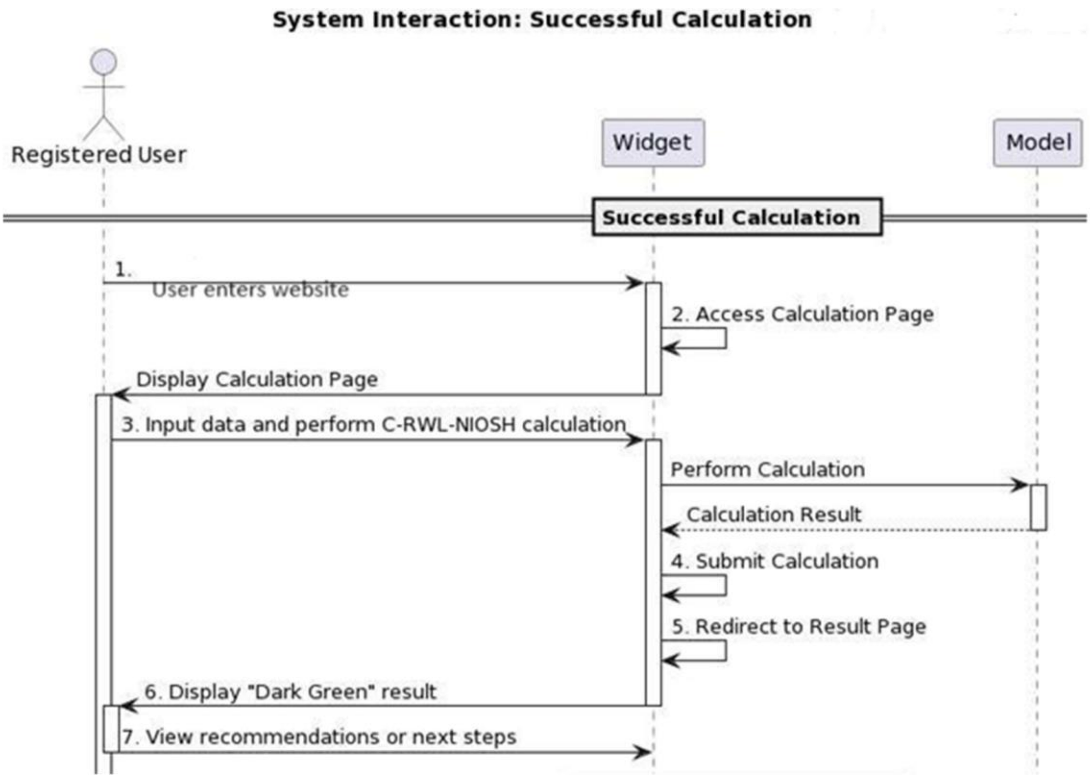


Figure 14: Sequence Diagram 1

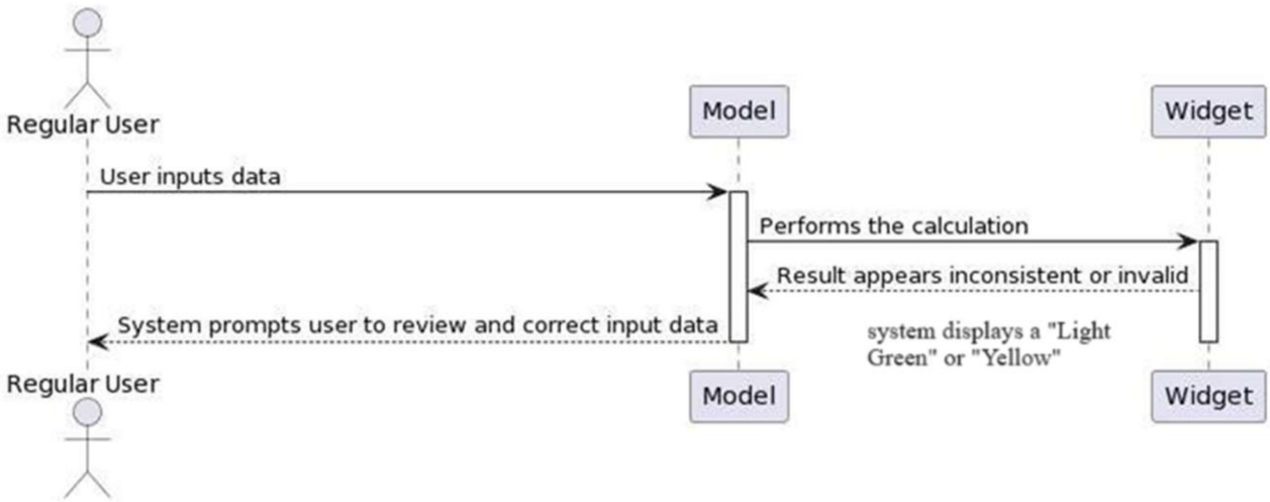


Figure 15: Sequence Diagram 2

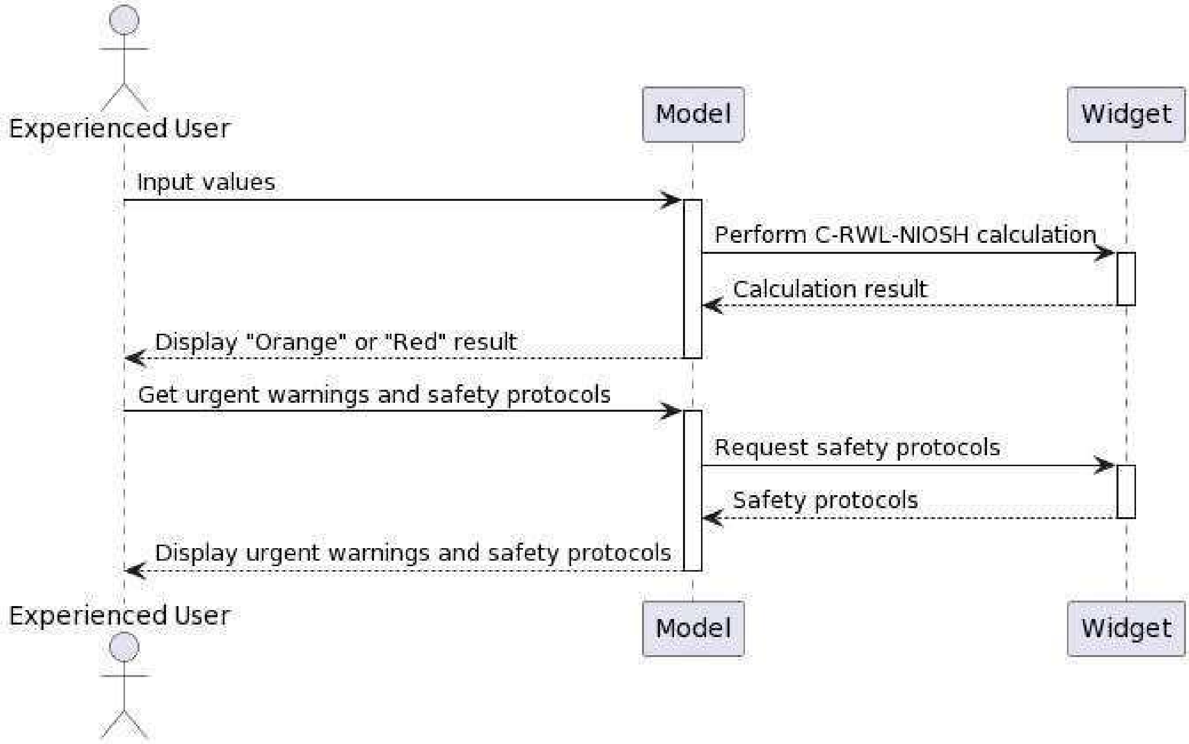


Figure 16: Sequence Diagram 3

3.1.3.7 UML Diagram

Figure 17: UML Diagram

3.1.4. Physical architecture

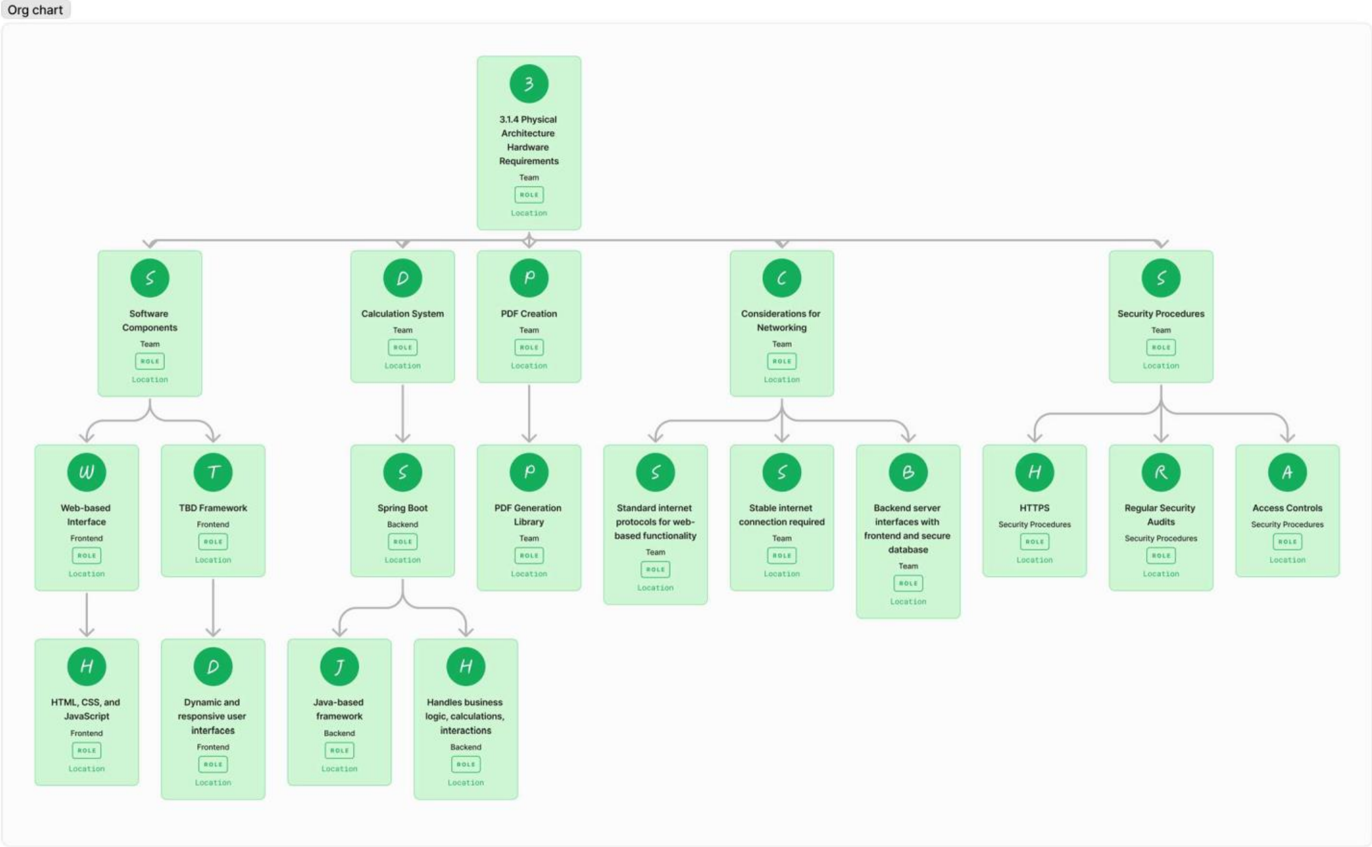


Figure 18: Physical Architecture

- <u>Hardware Requirements:</u> There are no particular hardware requirements for users of the C-NIOSH-RWL system because it is a software programme. It is meant to function on standard computing devices, including mobile phones, laptops, and desktop PCs. Design principles that are responsive offer compatibility across a range of screens and devices.

- <u>Software Components:</u>

  Frontend:

  Web-based interface: Created with HTML and CSS to allow for seamless user interaction.

  Bootstrap Framework: Used to create dynamic and responsive user interfaces that ensure a smooth user experience.

  Backend:

  Spring Boot: The backend is built using Spring Boot, a Java-based platform renowned for its effectiveness and simplicity of development. It performs computations and primary business logic.

PDF Creation:

PDF Generation Library: A relevant library or tool has been included into the system to make it easier to create printed and savable PDF reports.

- Considerations for Networking: Standard internet protocols are utilized by the system for web-based functionality. For users to use the programme and enter task parameters, they need a reliable internet connection.

- Security Procedures:

  The following procedures will be implemented to maintain data privacy and security:

  HTTP (Secure Data Communication Protocols) could be used to encrypt data transmission between the user's device and the server, protecting against potential threats.

  Regular Security Audits: Periodic examinations of the system's security will be performed, with the goal of discovering and resolving vulnerabilities as soon as possible.

Access Controls: To prevent unauthorized access to sensitive information, role-based access controls will be installed.

3.1.5. Materialization

The process of materialization entails converting abstract concepts and blueprints into an actual, working system. This entails outlining the networking, hardware, and software components in addition to any other implementation-related concerns.

3.1.6. Evaluation

In order to ensure that the produced C-NIOSH-RWL system is efficient, functional, and meets the required standards, the Software Engineering department conducted a complete analysis. The evaluation process includes user experience in addition to functional and non-functional criteria.

- Functional

Evaluation: Task Parameter
Entry:
Analyze the system's ability to let users to enter task parameters correctly.
Verify that the task parameters' visual representations—such as the meaning of "H" for the horizontal multiplier—are understandable and straightforward.

Calculation correctness: Assess the accuracy with which multipliers, RWL values, and Load Index (LI) values are calculated by the system.
Verify that the system appropriately interprets LI data and gives the job the appropriate risk rating.

Ergonomic Recommendations: Evaluate the system's ability to suggest significant ergonomic enhancements based on computed values.
Assess the recommendations made by the system for their application and usefulness.

Report Generation: Assess the system's capacity to produce thorough reports that incorporate all pertinent information.
Verify that printing and saving the reports in PDF format is simple.

- Non-Functional Evaluation:

User Experience (UX): To guarantee a positive UX and consistency with UX ideas, do usability testing.
Gather feedback from customers about the overall experience, ease of use, and clarity of the information.

Educational Value: Assess the system's ability to convey information concerning risk levels, RWL, LI, and job parameters.
Assess how well the system has helped students understand ergonomic concepts.

User Interaction: Investigate if users may give the analysis an ID for organizational reasons by using the system.
Evaluate how simple it is for users to navigate the system and finish tasks.

Performance: Evaluate response times for both simple computations and complex procedures.
Verify the system's scalability to make sure it can support at least 50 users concurrently.

- Security Evaluation:

Encryption of data: Verify if HTTPS, or secure data communication protocols, are being utilized to encrypt data while it is being transmitted.

Audits of security: Make sure that regular security audits are carried out to identify and address vulnerabilities as soon as feasible.

3.2. The name of the sub-system

Subsystem Department: Industrial Engineering

Subsystem Working Groups: Product Management, Project Management, Business Analyst (UI Design), User Experience

The goal of the industrial engineering team is to develop a system that complies with NIOSH regulations with the help of coding skills of software engineering team. The system serves the purpose of increasing efficiency and safety in workplace lifting tasks. The team is also responsible for providing a user-friendly interface and facilitating easy data entry, with accurate formulas and calculations.

3.2.1. Requirements

- Algorithms that calculate RWL according to NIOSH guidelines must be provided by the team.
- The system will be designed to help the workers in real-life workspaces; therefore, it must be easy for them to understand the interface and be able to calculate safe lifting limits. We can provide this ease of use for our end-users by adding guidance buttons that explain each multiplier’s meaning to our system.
- Integration of the system must be tested for efficiency and reliability. The main task of the system must be performed by different user personas, under different conditions and workloads in order to scale the effectiveness of the system feedback must be collected after this user-tests and revise the system according to feedback.

3.2.2. Technologies and Methods

In our Industrial Engineering team, we actively assess potential project risks using tools like a risk analysis matrix and a risk assessment table. These methods guide our strategic planning during the design and implementation stages. Moving ahead, we are gearing up for a critical phase of focused user testing. This upcoming testing period provide valuable insights to inform iterative enhancements, ensuring our system aligns harmoniously with user expectations. Our commitment to continuous fine-tuning and adjustment reflects our dedication to addressing challenges and optimizing the efficiency of our project.

3.2.3. Conceptualization

- The requirements, concerns, and systematic expectations identified while end-users' specified needs and expectations will also be considered.
- Industrial engineering department ensures that the system will be built according to NIOSH guidelines adherence and how the system comply with these standards.

3.2.5. Materialization

During materialization, the industrial engineering team prioritized a user-friendly experience. We commenced with Balsamiq wireframes and advanced towards the ultimate user interface, placing great emphasis on simplicity.

On the page for our R-NIOSH calculator, we incorporated a dedicated section with input fields for each multiplier. Enlightening boxes assist users, augmenting comprehension, and precise data input.

Following submission, the system engenders a page of results that showcases calculated values and furnishes valuable feedback. This loop guarantees that users acquire insights about the NIOSH method, thereby contributing to an enlightening user encounter.

3.2.5.1 Wireframe

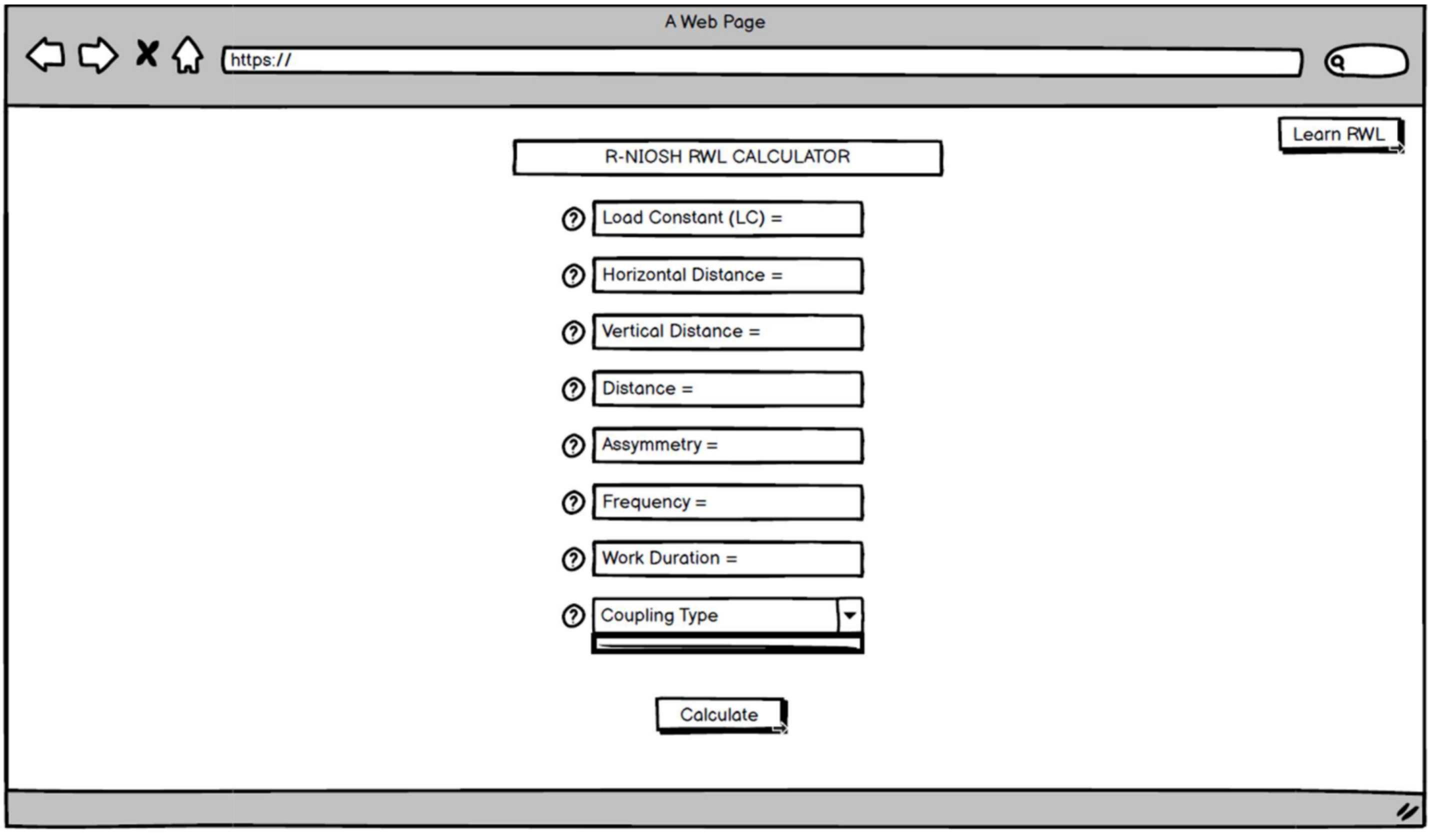


Figure 19: Wireframe 1

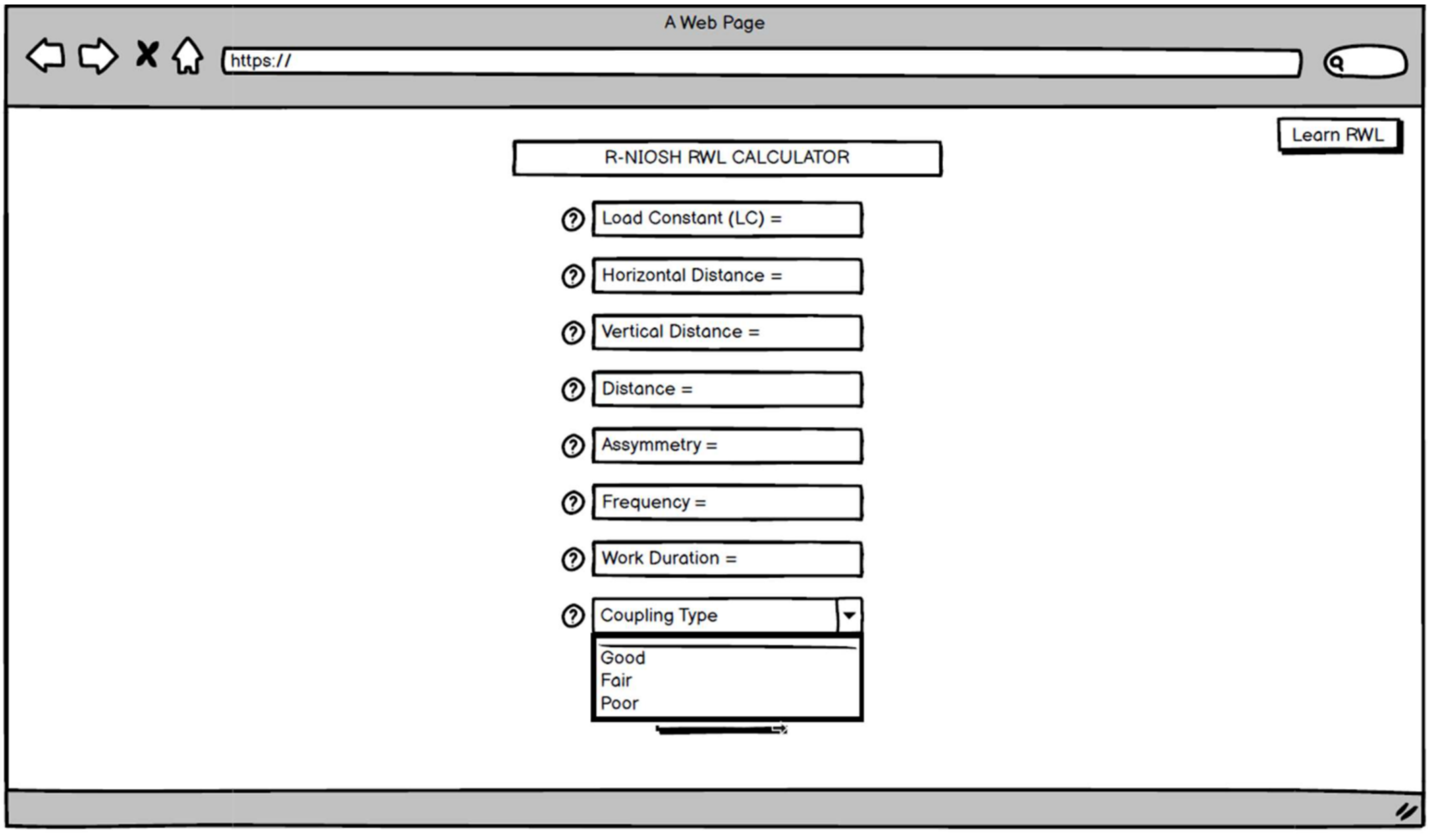


Figure 20: Wireframe 2

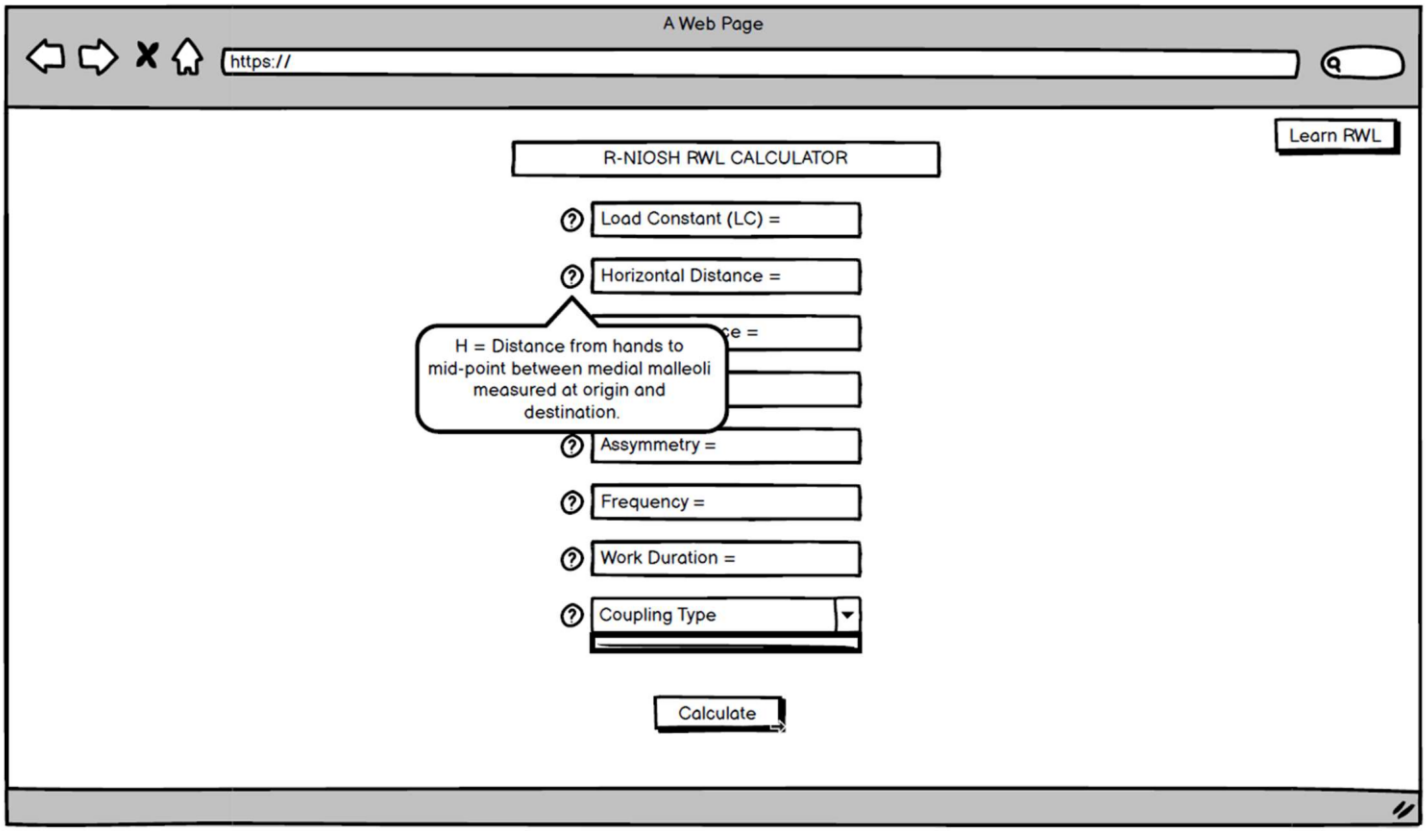


Figure 21: Wireframe 3

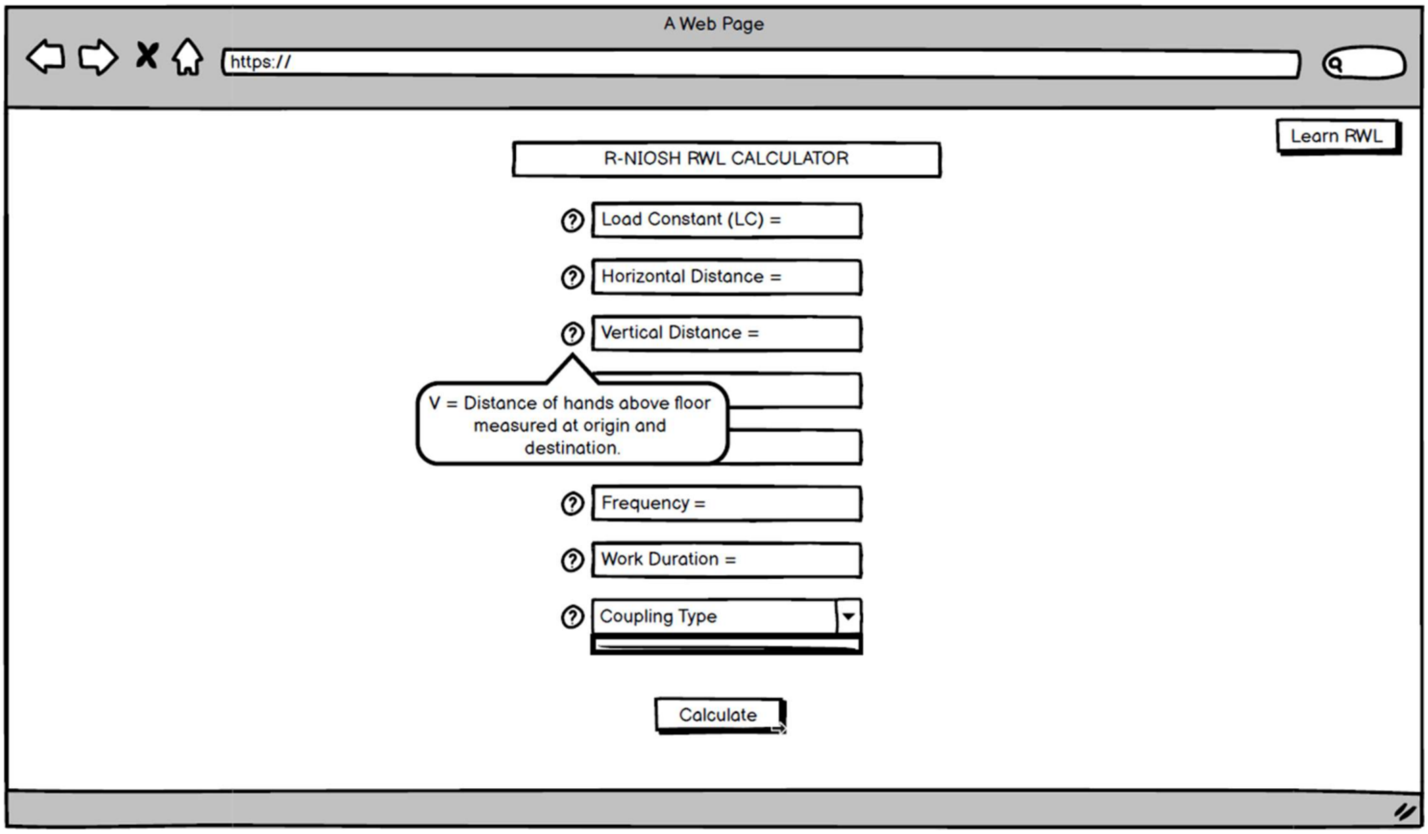


Figure 22: Wireframe 4

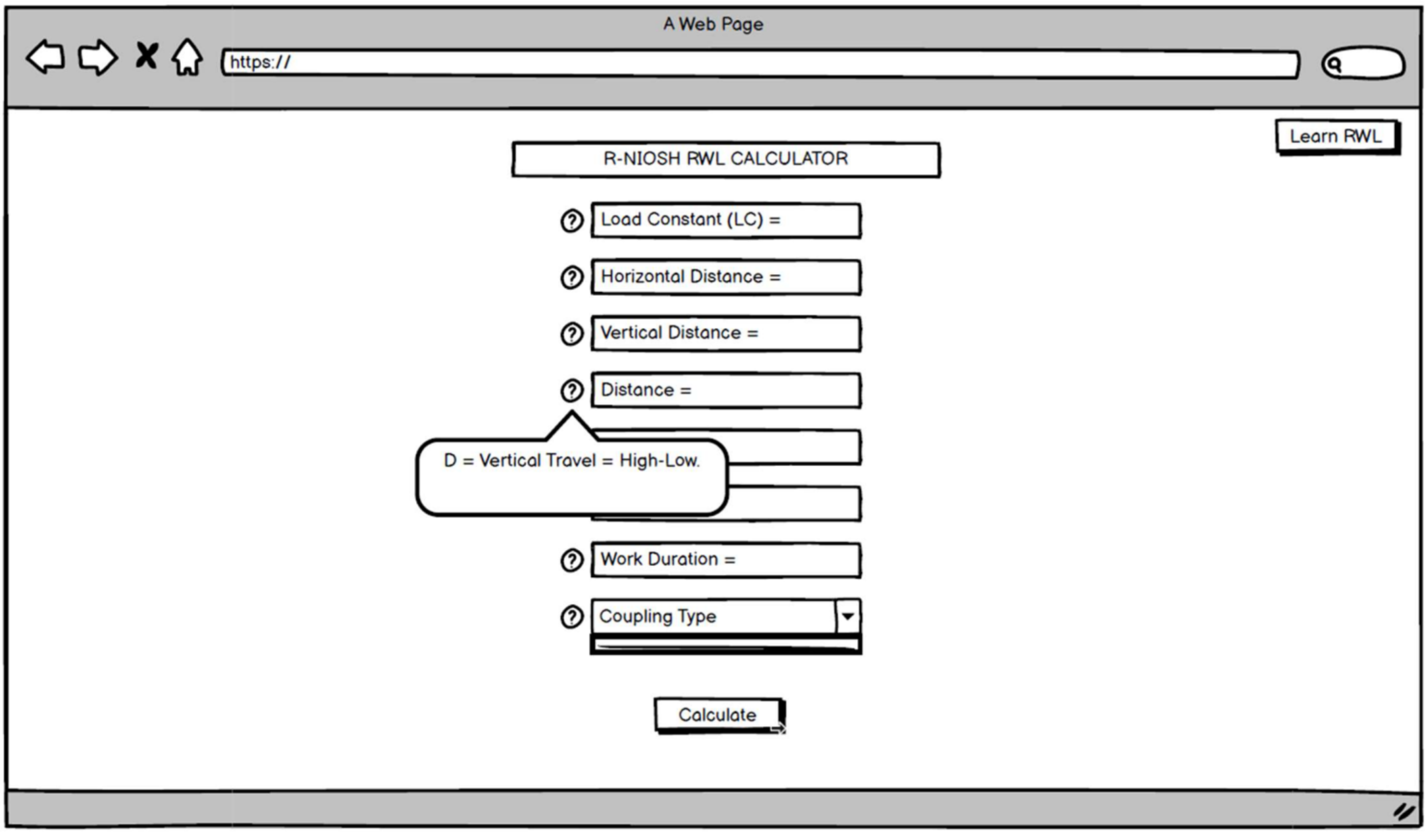


Figure 23: Wireframe 5

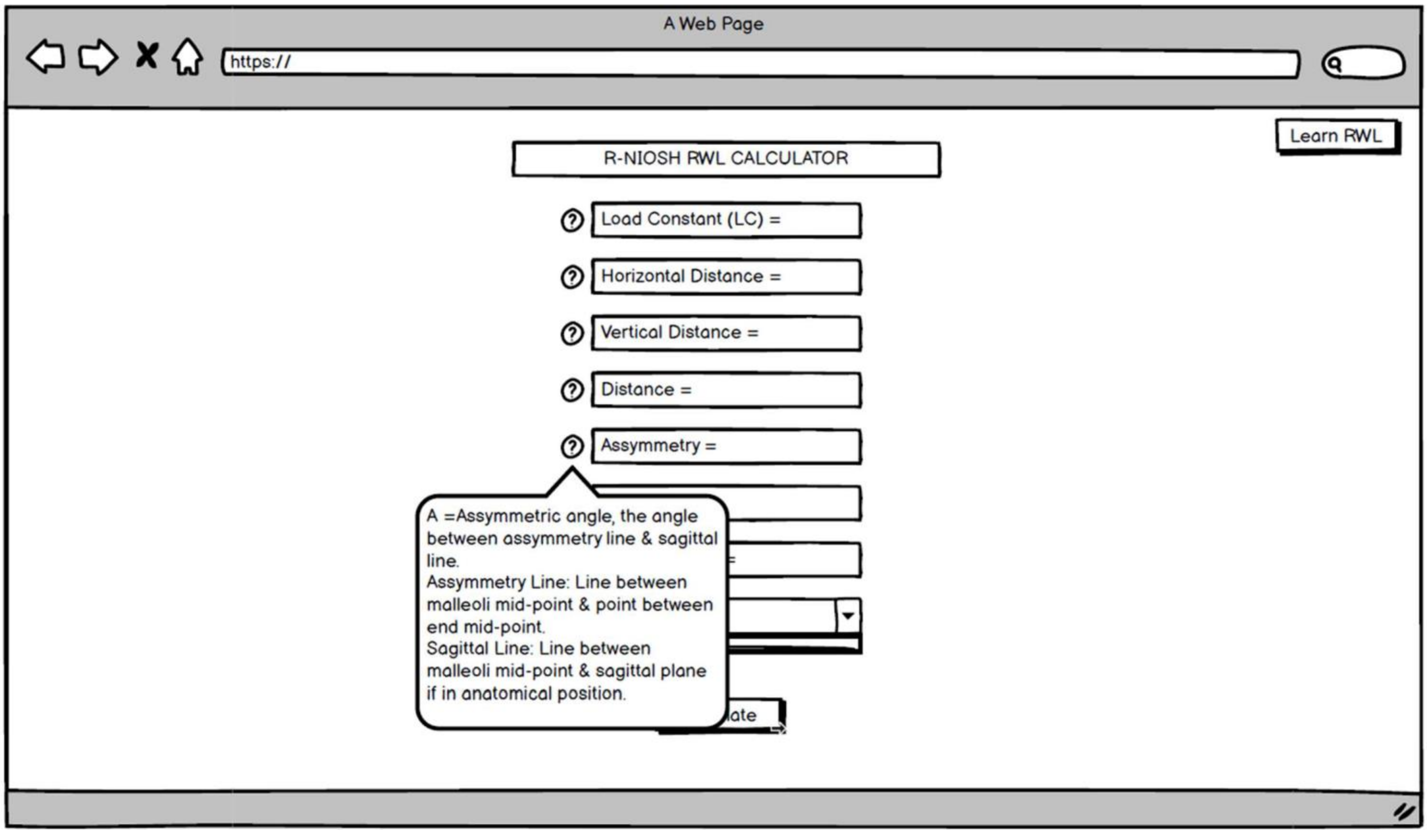


Figure 24: Wireframe 6

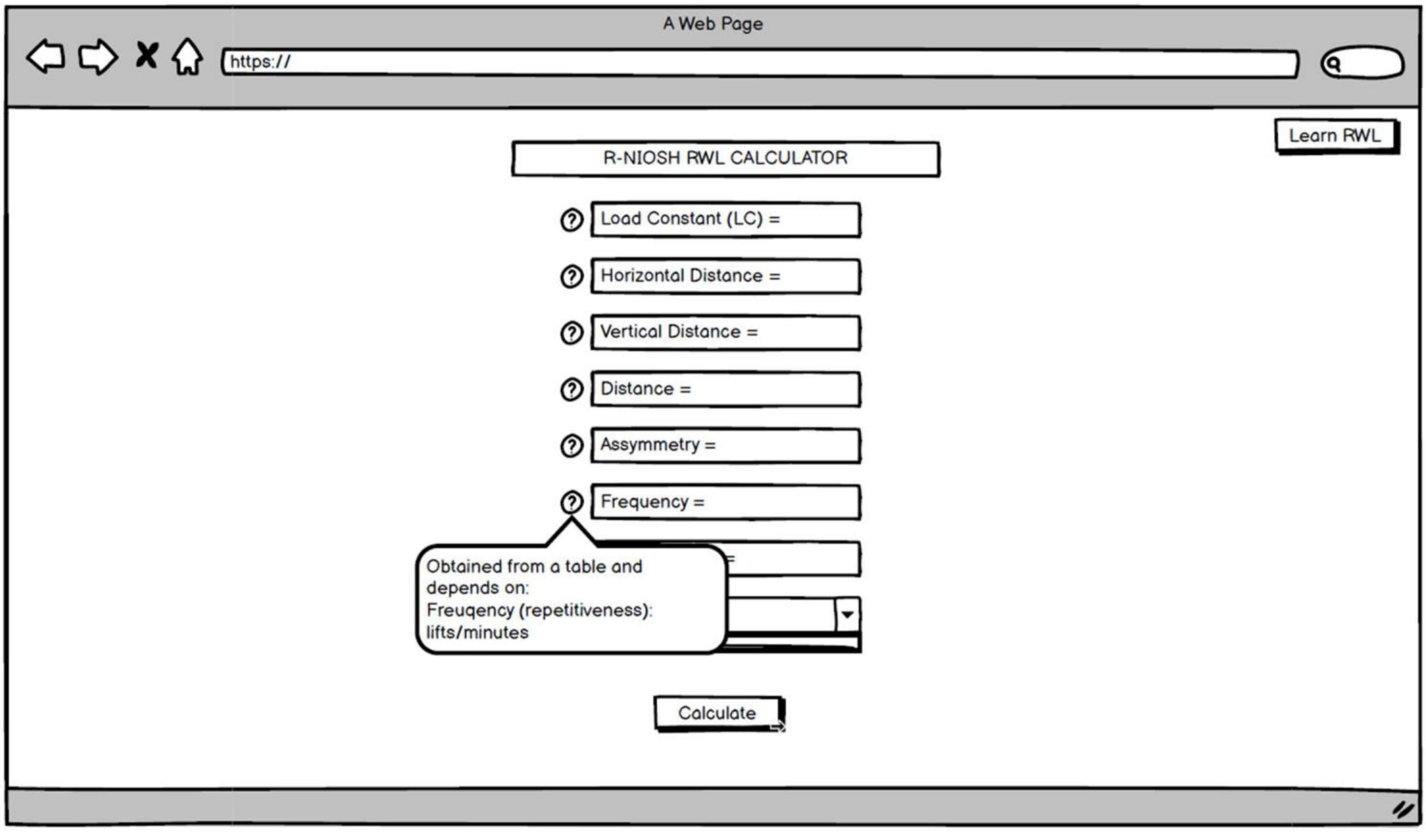


Figure 25: Wireframe 7

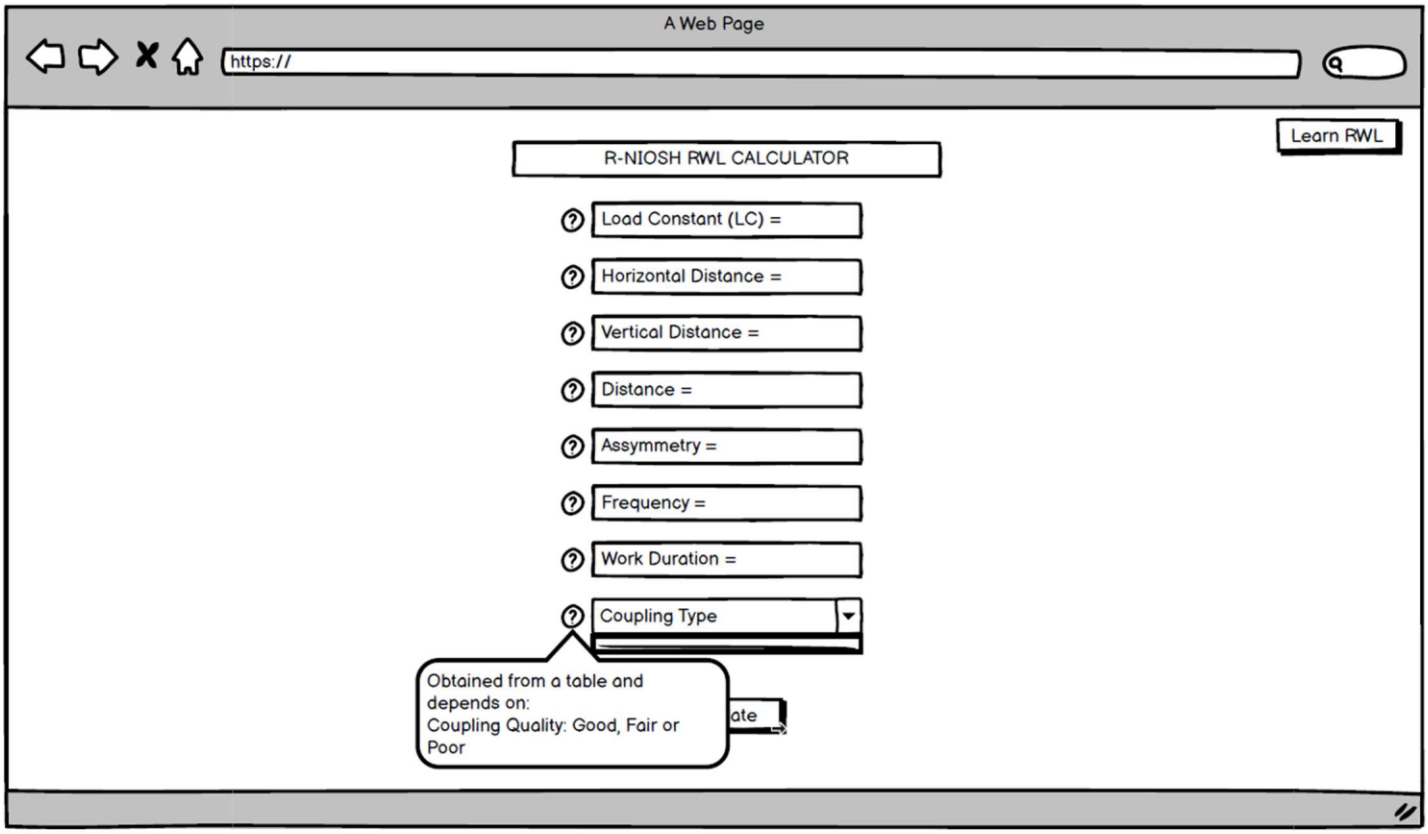


Figure 26: Wireframe 8

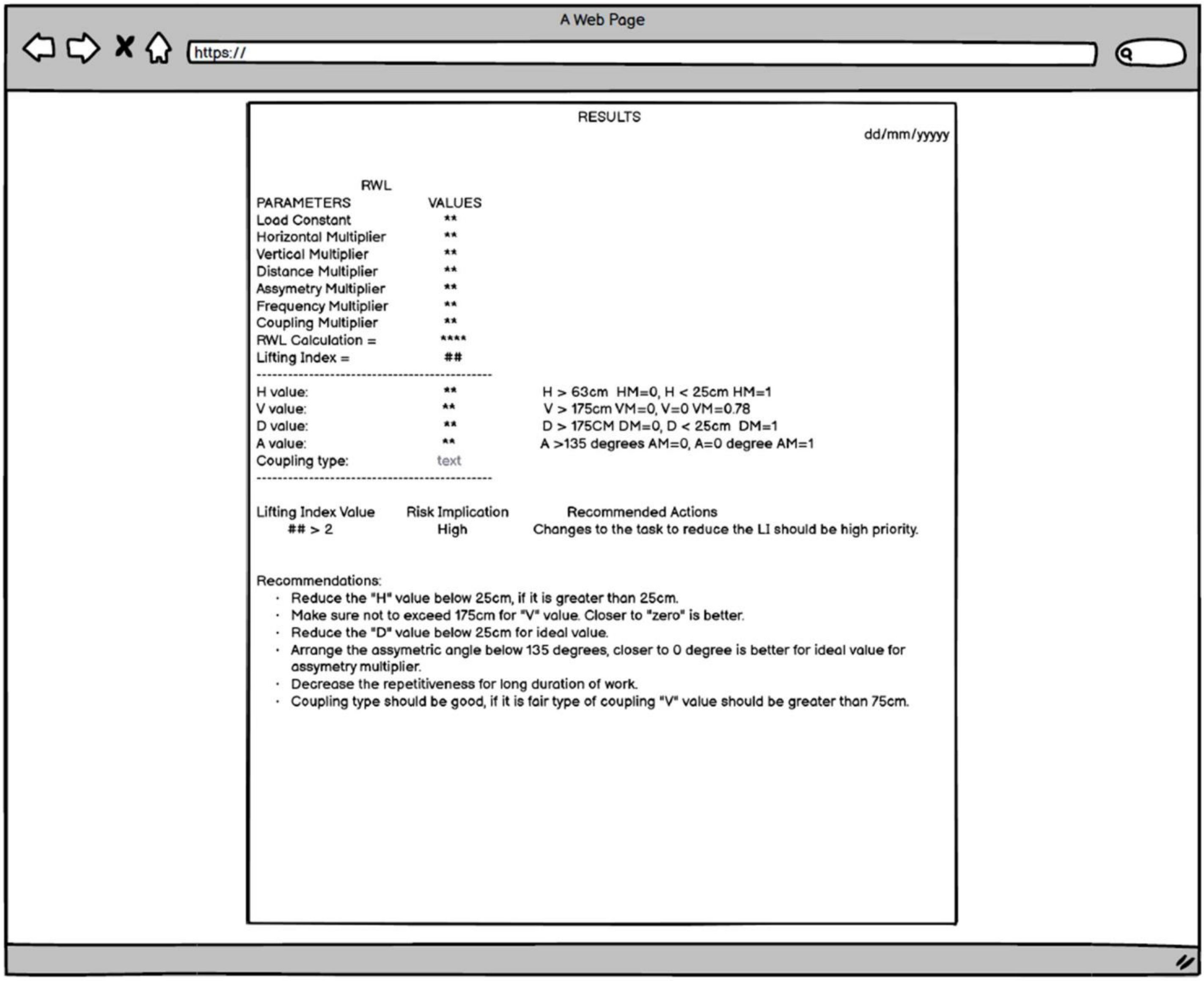


Figure 27: Wireframe 9

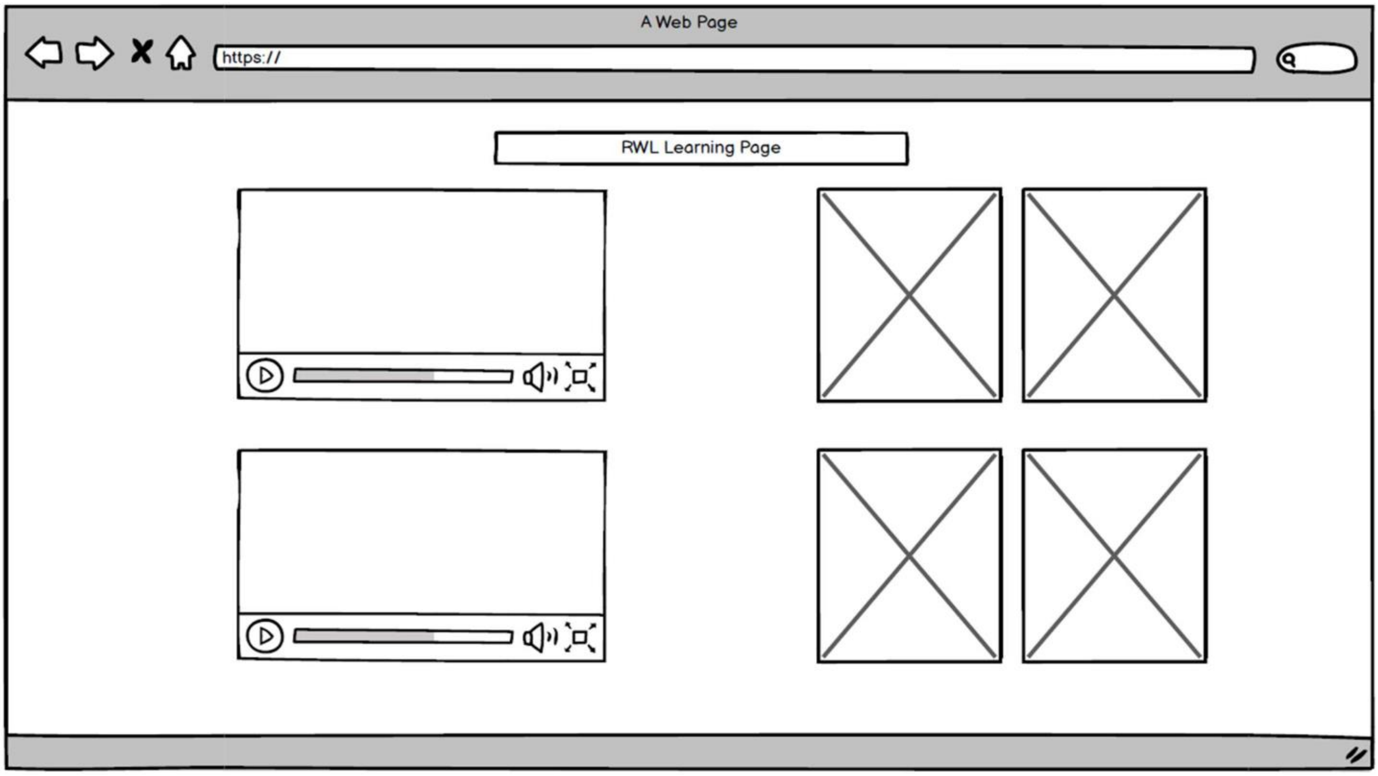
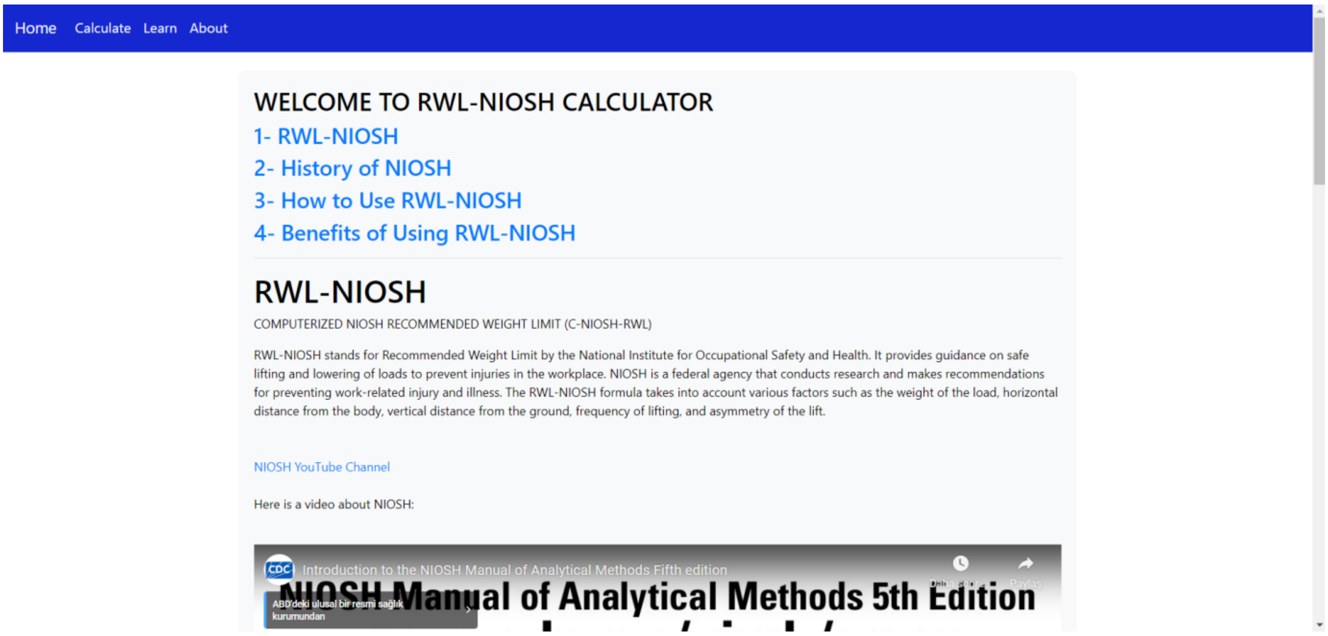
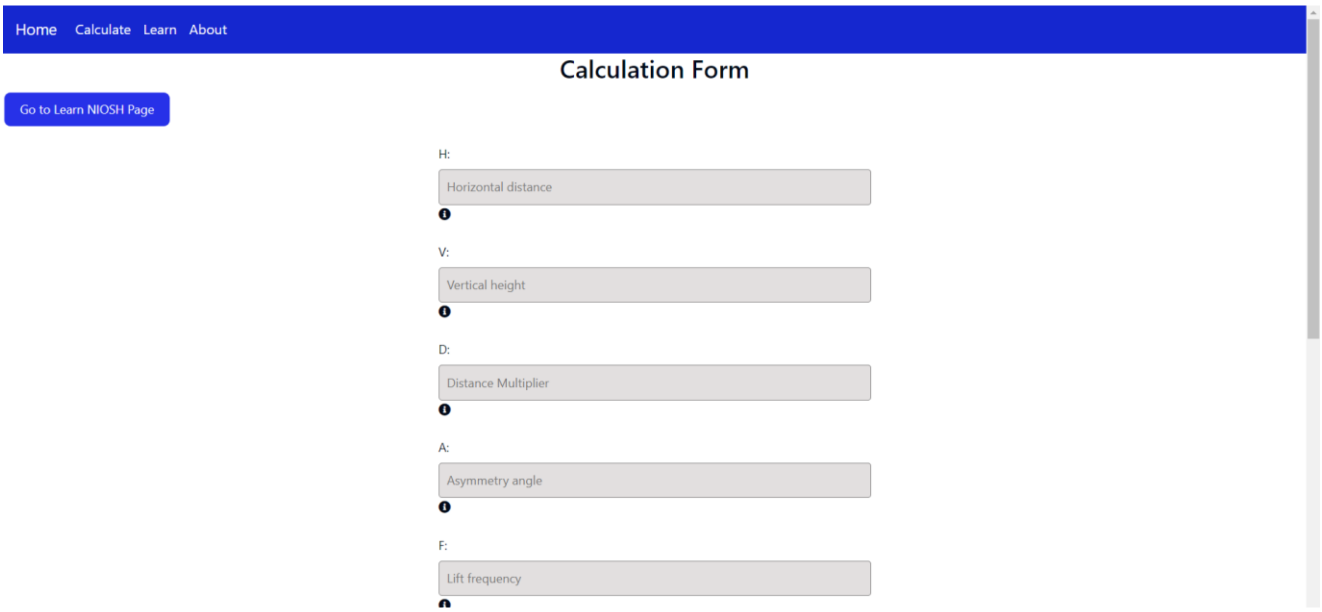


Figure 28: Wireframe 10

3.2.6. Evaluation

The evaluation of the industrial engineering section involves key assessments such as, RWL calculation through algorithm validation and conformity with NIOSH guidelines, conducting usability testing to assess system’s ease of use and efficiency, conducting performance checks for flawless functionality and accuracy of the system. It further comprises quantifying the system's influence on ergonomic conditions and workplace safety, verifying regulatory compliance and ethical standards, and establishing mechanisms for feedback in order to continually enhance. This assessment strives to authenticate precision, usability, adherence to standards, and overall efficiency in increasing workplace safety and efficiency.





Work Duration:

hours/day

Coupling Type:

Good

L:

Actual weight

Calculate

Home Calculate Learn About

About Us

Purpose of the Project

NIOSH RWL is a quantitative method for ergonomically analyzing and improving manual lifting tasks. The objective of this project is to develop a software (web-based or mobile) for application of NIOSH RWL method. The software will be used in the INE2012 work study and ergonomics classes for educational purposes.

Software Team

Functional Requirements:

- Allow the user to enter task parameters.
- Visually show parameters of the task (e.g., what H means for horizontal multiplier).
- Calculate multiplier values.
- Calculate RWL value.
- Calculate Load Index (LI) value.
- Interpret LI value and give the risk level for the task.
- Propose ergonomic improvements.
- Generate a report to include all the information above.

The functional requirements listed above were developed by our software team :

- **Hermann Yunus Knudsen**

Industrial Engineering Team

Non-Functional Requirements:

- Offer good UX and be developed in line with UX principles.
- Be educational and provide info about task parameters, RWL, LI, and risk levels.
- Allow giving an ID to the analysis (e.g., task ID number, task name, brief task description).
- Give a report that is easy to print and save (e.g., PDF format).

The functional requirements listed above were developed by our industrial engineering team :

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Acknowledgements

We extend our sincere appreciation to our esteemed advisors, Assoc. Prof. Dr. Oğuzhan Erdinç in the field of Industrial Engineering and Assistant Prof. Özge Yücel Kasap specializing in Software Engineering. Their unwavering support, insightful guidance, and depth of expertise have been invaluable

The functional requirements listed above were developed by our industrial engineering team :

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  Website: cagla

Acknowledgements

We extend our sincere appreciation to our esteemed advisors, Assoc. Prof. Dr. Oğuzhan Erdinç in the field of Industrial Engineering and Assistant Prof. Özge Yücel Kasap specializing in Software Engineering. Their unwavering support, insightful guidance, and depth of expertise have been invaluable throughout our project. We are genuinely grateful for the opportunity to benefit from their mentorship, which has significantly contributed to our academic and professional growth.

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  Website: Özge Yücel Kasap
- **Assoc. Prof. Dr. Oğuzhan Erdinç**
  Email: oguzhan.erdinc@bau.edu.tr
  Website: Oğuzhan Erdinç

Results

Date: Tue May 21 2024

NAME	VALUE
RWL	**188.78**
Horizontal Multiplier	**8.33**
Vertical Multiplier	**0.78**
Distance Multiplier	**2.32**
Asymmetry Multiplier	**0.99**
Frequency Multiplier	**0.55**
Coupling Multiplier	**1.0**
Load Index	**0.02**

NAME	VALUE
Horizontal Distance	**3.0**
Vertical Height	**3.0**
Distance	**3.0**
Asymmetry Angle	**3.0**
Lift Frequency	**3.0**
Duration of the Task	**3.0**
Coupling Type	**GOOD**
Actual Weight	**3.0**

Lifting Index Value

0.02

Risk Implication

VERY LOW

Recommended Actions

None in general for the healthy working population

Load Index	**0.02**	Actual Weight	**3.0**

Lifting Index Value

0.02

Risk Implication

VERY LOW

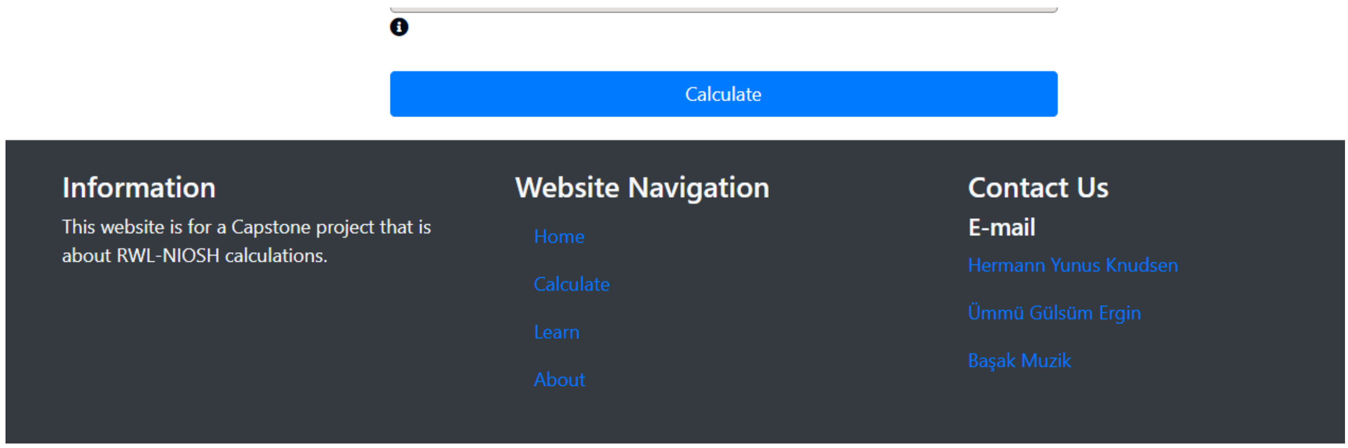
Recommended Actions

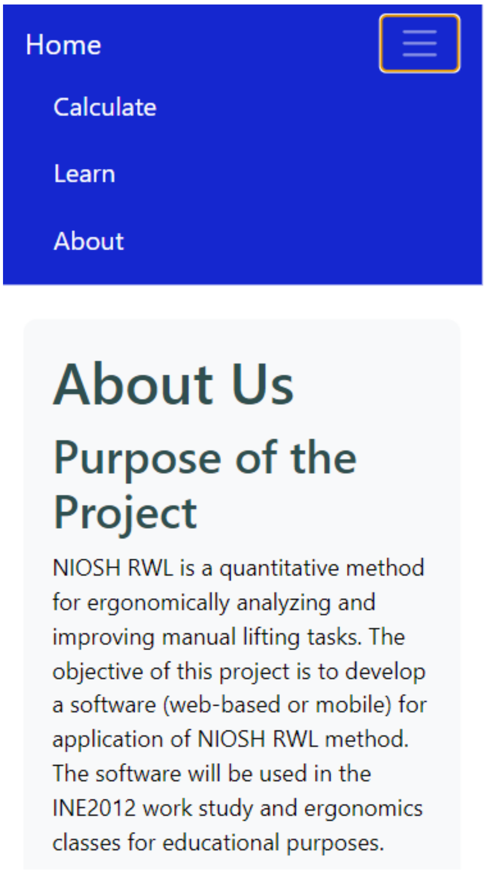
None in general for the healthy working population.

N-RWL-CALCULATION RECOMMENDATIONS
Setting the V value to 75 cm is ideal for **VM**.
Setting the H value to 25 cm is ideal for **HM**.
Setting the D value to 25 cm is ideal for **DM**.
Decreasing the A value to 0 degree is ideal for **AM**.
Decreasing the work duration and repetitiveness for 1 worker is ideal for **FM**.
In order to decrease the **work duration** per worker it is recommended to make job rotations within the organization.
A good coupling is ideal for **CM**.

Return to Calculation Page

Download PDF


Calculate
Information
This website is for a Capstone project that is about RWL-NIOSH calculations.
Website Navigation
Home
Calculate
Learn
About
Contact Us
E-mail
Hermann Yunus Knudsen
Ümmü Gülsüm Ergin
Başak Muzik


Home
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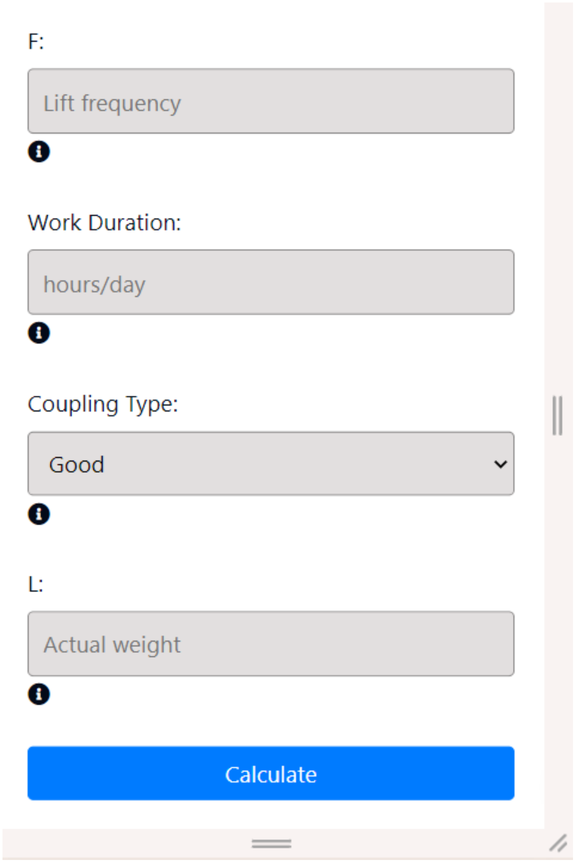
About Us
Purpose of the Project
NIOSH RWL is a quantitative method for ergonomically analyzing and improving manual lifting tasks. The objective of this project is to develop a software (web-based or mobile) for application of NIOSH RWL method. The software will be used in the INE2012 work study and ergonomics classes for educational purposes.


F:
Lift frequency
Work Duration:
hours/day
Coupling Type:
Good
L:
Actual weight
Calculate

4. INTEGRATION AND EVALUATION

4.1. Integration

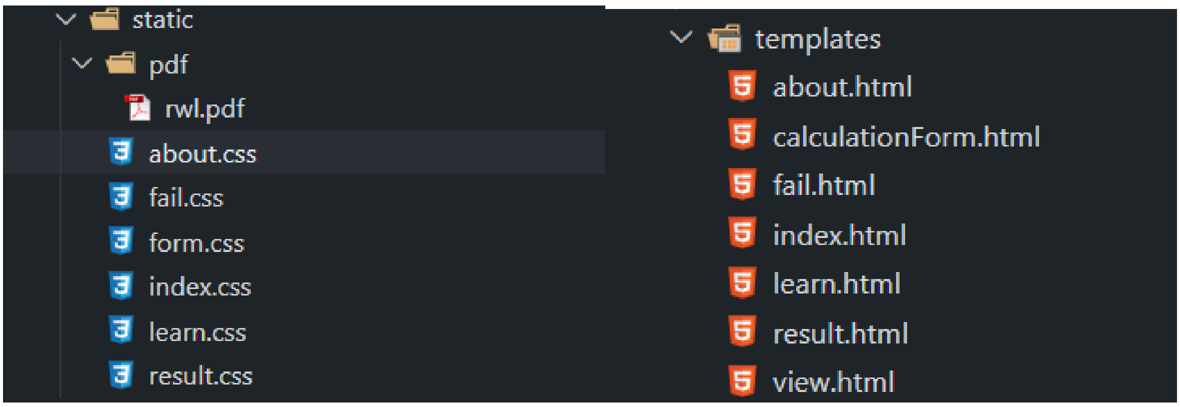
Setting up the frontend development environment (using tools like Vscode, Intellij, and Postman) and integrating the backend into the IDE are essential in System Development. In order to receive data from the frontend and handle HTTP requests, request processing must be implemented on the backend. To handle different kinds of requests (such creating reports or doing computations), the backend controller creates a variety of endpoints.

Frontend:

Six core classes, each with a matching CSS, make up the frontend portion of our project. Custom-written elements are included to make the frontend responsive. Furthermore, Bootstrap has also been used in order to present a responsive page. Also, Javascript is used for the date.

Date: Thu May 16 2024

The site opens first, giving visitors a quick overview. The calculator on the calculation form can then be used by users, and the result page allows users to download the results in PDF format. Because of its educational nature, this system lets users who aren't familiar with it watch movies and read PDFs to learn what they need to know.



About the structure of the front-end HTML:

An opening <html> tag and the standard HTML5 doctype declaration mark the start of the document structure.

The required metadata, including the external CSS libraries, font-awesome libraries, and the page title, are contained in the <head> section.

Content is contained within the <body> tag and wrapped within a <div> element with the class "container" for layout reasons.

"NIOSH RWL Calculator" (<h2>) is the page's primary heading.

To collect input data for RWL computation, a <form> element is set up. The following parameters are related to an input field: asymmetry, frequency, length of work, coupling type, load constant, horizontal and vertical distances, and frequency.

Each input field has a label tag (<label>) describing its purpose within a <div> element for visual clarity.

Some input fields have <span> elements that are positioned after them with font-awesome icons that are encased in <i> tags. These elements function as tooltips that provide further details about the input field that they are following. Lastly, to start the form submission process, a "Calculate" button (<button>) is available.

```
<button type="submit" class="btn btn-primary btn-submit">Calculate</button>
```

calculationForm.html ×

BOOT-INF > classes > templates > calculationForm.html > html > body

Click here to ask Blackbox to help you code faster

```html
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>Calculation Form</title>
    <link rel="stylesheet" type="text/css" href="form.css">
    <link rel="stylesheet" href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/5.15.4/css/all.min.css">
    <link href="https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/css/bootstrap.min.css" rel="stylesheet">
</head>
<body>

<nav class="navbar navbar-expand-lg navbar-dark navbar-custom">
    <a class="navbar-brand" href="/">Home</a>
    <button class="navbar-toggler" type="button" data-toggle="collapse" data-target="#navbarSupportedContent"
aria-controls="navbarSupportedContent" aria-expanded="false" aria-label="Toggle navigation">
        <span class="navbar-toggler-icon"></span>
    </button>

    <div class="collapse navbar-collapse" id="navbarSupportedContent">
        <ul class="navbar-nav mr-auto">
            <li class="nav-item">
                <a class="nav-link" href="/calculate">Calculate</a>
            </li>
            <li class="nav-item">
                <a class="nav-link" href="/learn">Learn</a>
            </li>
            <li class="nav-item">
                <a class="nav-link" href="/about">About</a>
            </li>
        </ul>
    </div>
</nav>

<h2>Calculation Form</h2>
```

```html
<h2>Calculation Form</h2>

<a href="/learn" class="a-learn"><button>Go to Learn NIOSH Page</button></a>

<form th:action="@{/calculate}" method="post">
    <label for="h">H:</label>
    <input type="number" id="h" name="H" th:value="${H}" placeholder="Horizontal distance"><br>
    <div class="info-tooltip" title="H = Distance from hands to mid-point between medial malleoli measured at
origin and destination.">
        <i class="fas fa-info-circle"></i>
    </div>

    <label for="v">V:</label>
    <input type="number" id="v" name="V" th:value="${V}" placeholder="Vertical height"><br>
    <div class="info-tooltip" title="V = Distance of hands above floor measured at origin and destination.">
        <i class="fas fa-info-circle"></i>
    </div>

    <label for="d">D:</label>
    <input type="number" id="d" name="D" th:value="${D}" placeholder="Distance Multiplier"><br>
    <div class="info-tooltip" title="D = Distance">
        <i class="fas fa-info-circle"></i>
    </div>

    <label for="a">A:</label>
    <input type="number" id="a" name="A" th:value="${A}" placeholder="Asymmetry angle"><br>
    <div class="info-tooltip" title="A =
    Asymmetric angle, the angle between asymmetry line & sagittal line.
    Asymmetry Line: Line between malleoli mid-point & point between end mid-point.
    Sagittal Line: Line between malleoli mid-point & sagittal plane if in anatomical position.">
```

about.css

BOOT-INF > classes > static > about.css > ...

Click here to ask Blackbox to help you code faster

```css

/* Custom CSS for blue navbar */
 .navbar-custom {
    background-color: #1527cf;
    /* Blue color */
}
 .navbar-custom .navbar-nav .nav-link {
    color: #fff;
    font-size: 18px; /* Larger font size */
    padding: 10px 20px; /* Increased padding */
    /* White color for links */
}
 .navbar-custom .navbar-nav .nav-link:hover {
    color: #f0f0f0;
    /* Lighter shade of white on hover */
    background-color: #0056b3;
    /* Darker shade of blue on hover */
    border-radius: 10px;
}
.navbar-custom .navbar-nav .nav-item .nav-link {
     color: white; /* Text color */
    }

/* Background color for the main content area */
.content-background {
  background-color: #f8f9fa; /* Light gray */
  padding: 20px;
  border-radius: 10px;
}
```

The primary content section of a website and a customizable navigation bar (navbar) are styled using the CSS code block.

A modified version of the navigation bar is defined by the ".navbar-custom" class. With "#1527cf" as the backdrop color, a blue tone is produced. Links inside the navbar are styled differently by the rules ".navbar-custom.navbar-nav.nav-link" and ".navbar-custom.navbar-nav.nav-link:hover". The backdrop color becomes dark blue, and the text color becomes light blue when the link text is hovered over. The link text is now set to white. To make the links stand out more to users, additional padding and a larger font size have been added.

The backdrop color of the primary content section is set to "#f8f9fa" by the ".content-background" class, giving it a light gray tone. To improve the content area's look and arrangement, additional characteristics are defined for it, such as border-radius and padding.

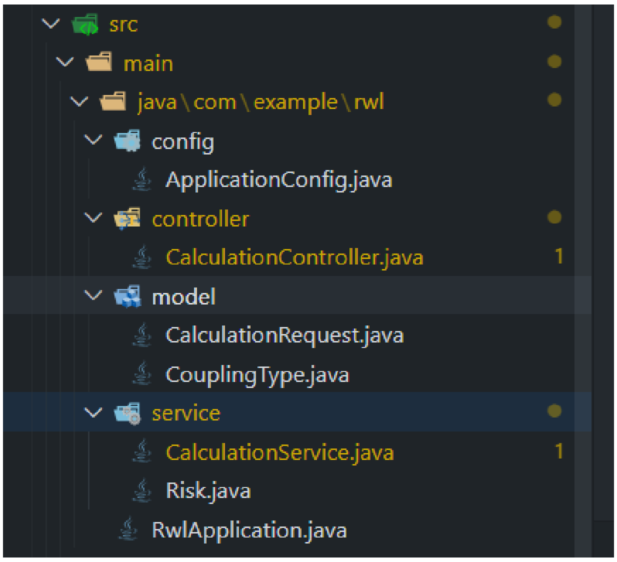
Backend :

Main Application (RwlApplication.java): The Spring Boot application's entry point, the RwlApplication class, is in charge of initializing and operating it.

Incoming data is processed, calculations are made, and relevant reports or results are returned by the backend processing layer in response to requests sent from the frontend. The service layer provides suitable error handling for exception processing while isolating business logic to guarantee concern separation.

```java
package com.example.rwl;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class RwlApplication {
    public RwlApplication() {
    }

    public static void main(String[] args) {
        SpringApplication.run(RwlApplication.class, args);
    }
}
```

```
\Local\Temp\cp_7mh8jc1nedbcpjey6h6ykvysj.argfile' 'com.example.rwl.RwlApplication'

  .   ____          _            __ _ _
 /\\ / ___'_ __ _ _(_)_ __  __ _ \ \ \ \
( ( )\___ | '_ | '_| | '_ \/ _` | \ \ \ \
 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/
 :: Spring Boot ::                (v3.2.4)

2024-05-15T16:15:45.358+03:00  INFO 16724 --- [rwl] [           main] com.example.rwl.RwlApplication           : Starting RwlApplication using Java 17.0.1
1 with PID 16724 (C:\Users\casper\OneDrive\Masaüstü\kodlama şeyleri mezun olunca sil\kesinfinal\rwl\target\classes started by casper in C:\Users\casper\On
eDrive\Masaüstü\kodlama şeyleri mezun olunca sil\kesinfinal)
2024-05-15T16:15:45.368+03:00  INFO 16724 --- [rwl] [           main] com.example.rwl.RwlApplication           : No active profile set, falling back to 1
default profile: "default"
2024-05-15T16:15:47.943+03:00  INFO 16724 --- [rwl] [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat initialized with port 8080 (http)
2024-05-15T16:15:47.970+03:00  INFO 16724 --- [rwl] [           main] o.apache.catalina.core.StandardService   : Starting service [Tomcat]
2024-05-15T16:15:47.970+03:00  INFO 16724 --- [rwl] [           main] o.apache.catalina.core.StandardEngine    : Starting Servlet engine: [Apache Tomcat/1
0.1.19]
2024-05-15T16:15:48.121+03:00  INFO 16724 --- [rwl] [           main] o.a.c.c.C.[Tomcat].[localhost].[/]       : Initializing Spring embedded WebApplicati
```



Config Layer (ApplicationConfig.java):

The @Configuration annotation indicates the ApplicationConfig class as the Spring application's configuration class.

Its computationRequest() function generates a Spring bean, which is then added to the Spring container. An instance of the CalculationRequest class is created and returned by this @Bean-annotated function. As a result, many components inside the Spring application can share and inject these objects.

Control Layer (CalculationController.java):

The application's central control layer, CalculationController, is responsible for handling computation-related HTTP requests and informing users of the results. Dependencies like CalculationService and TemplateEngine, which are necessary for carrying out computations and displaying views, are initialized by the class upon instantiation.

In order to route users to different pages such as the homepage, learning materials, about section, and general view page, the controller creates methods to handle distinct HTTP GET requests. It also has functions to manage the showing of a calculation form, data submission for calculations, and rendering of success or failure pages according to parameters entered. It manages the whole calculation process by using the calculate() function to compute multipliers, the Load Index (LI), and the Risk of Whole-body Vibration Load (RWL) after validating the input data. Using the computed LI value as a guide, this method routes viewers to the relevant pages. Additionally, the controller uses the downloadPDF() function to allow users to download a PDF report that summarizes the results of the calculation. It contains the logic to turn HTML material into a PDF document with the help of the iText library and the Thymeleaf template engine, improving user experience and offering extensive reporting features.

The application's resilience in identifying and resolving ergonomic issues is further enhanced by a private function called riskValue(), which classifies LI values into various risk levels and recommends appropriate steps to reduce risks.

Model Layer (CouplingType.java, CalculationRequest.java):

Two classes, CalculationRequest and CouplingType, are defined in the application's model layer.

To encapsulate input parameters for a computation, a data transfer object (DTO) is represented by the CalculationRequest class. There are fields for load constants, asymmetry (A), distance (D), vertical (V), horizontal (H), frequency (F), work time, coupling type, and load (L). You can use the getter and setter methods to access these fields. There is no way to change the fixed value of 23.0 for the load constant. The class makes it easier for the application's client and server components to exchange computation parameters.

Three types of coupling are represented by the CouplingType enum: GOOD, FAIR, and POOR. These enum constants specify the coupling's quality or state, which can be utilized in calculations or other application sections to identify variables influencing the result of the computation. The enum makes code easier to comprehend and maintain by offering a predetermined set of coupling type possibilities.

When combined, these model classes help create an application-wide organized representation of coupling types and calculation parameters, which makes data transfer easier and ensures consistency in the way input data is handled.

Service Layer (CalculationService.java):

Located at the head of the application architecture's service layer, the CalculationService class has a powerful set of functions designed to perform complex calculations that are essential for evaluating ergonomic problems. The class takes a CalculationRequest object as an input when it is instantiated, and it carefully captures a range of necessary input parameters that are needed for the subsequent calculations. With the aid of complex mathematical algorithms and industry-standard formulas, the service carefully coordinates a variety of computations, each carefully planned to assess distinct aspects of ergonomic risks.

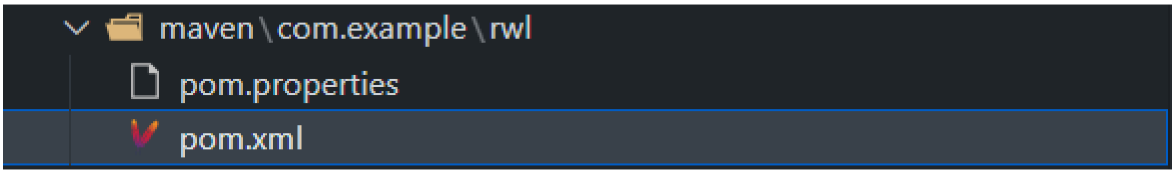
In order to account for the subtle differences in load distribution, the horizontalMultiplier() method, for example, carefully computes the horizontal multiplier by carefully balancing a fixed constant with the input parameter H. In a similar vein, the verticalMultiplier() technique makes use of a well-constructed mathematical formula to fine-tune the multiplier according to the absolute difference between the input parameter V and a preset threshold, providing a detailed assessment of vertical load factors.

Moreover, the distanceMultiplier() and asymmetryMultiplier() functions explore the complex domains of distance and asymmetry, respectively, skillfully adjusting multipliers to account for the finer points included in ergonomic evaluations.

In addition to these computations, the frequencyMultiplier() function demonstrates an advanced comprehension of workload dynamics by careful multiplier calibration based on the intricate relationship between frequency (F), vibration intensity (V), and work duration; this provides an exhaustive assessment of ergonomic hazards in various contexts.

Furthermore, couplingMultiplier() skillfully handles the complexities of coupling kinds (GOOD, FAIR, or POOR), modifying multipliers according to the subtleties of vibration coupling and providing a comprehensive assessment of coupling-related ergonomic hazards.

The CalculationService class is fundamentally the epitome of technical brilliance, carefully weighing accuracy, economy, and dependability to provide unmatched insights on ergonomic risks. Encapsulating complex mathematical algorithms and industry-standard formulas, the service is both a fundamental component of the application's operation and a demonstration of the dedication to providing state-of-the-art ergonomic risk assessment solutions.



A Maven project's Project Object Model (POM) configuration file, which describes the build configurations, dependencies, and other crucial project metadata, is represented by an XML file. In the metadata section, information about the project is provided, including its name, version, group ID, artifact ID, and brief purpose statement. To further ensure uniformity and compliance with accepted standards, the file also inherits configurations from the parent project, spring-boot-starter-parent. The dependencies section enumerates the libraries and frameworks needed for the project, including additional requirements for testing, PDF creation, HTML processing, and servlet support, as well as Spring Boot starters for Thymeleaf and web functionality.

Lastly, the build configuration lists the Maven plugins used in the process of building the application. Notably, this includes the Spring Boot Maven plugin. When combined, these POM files provide as an all-inclusive guide for handling build procedures, configurations, and dependencies in projects—a crucial function for guaranteeing the Maven-based project's seamless development and implementation.

```xml
<groupId>com.example</groupId>
<artifactId>rwl</artifactId>
<version>0.0.1-SNAPSHOT</version>
<name>rwl</name>
<description>C-RWL-NIOSH Capstone Project</description>
<properties>
  <java.version>17</java.version>
</properties>
<dependencies>
  <dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-thymeleaf</artifactId>
  </dependency>
  <dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-web</artifactId>
  </dependency>

  <dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-test</artifactId>
    <scope>test</scope>
  </dependency>
```

Hosting:

Since we haven't made any financial investments in the project or purchased a domain yet, we temporarily used Amazon Web Services (AWS).

However, we'll need to get a domain name in order to make the project permanently available. To make use of Amazon's hosting services, we have to do some certain actions. To publish the project, we would need to create an AWS account, after which we could either deploy an EC2 instance or host static material on S3. The project might then be made available online by acquiring a domain name and setting up DNS settings. The safe and effective functioning of the project depends on the implementation of security and monitoring protocols.

4.2. Evaluation

In the meantime, the evaluation phase is crucial in determining the success of the C-NIOSH-RWL system. Evaluation includes user testing and statistical analysis of UX data. This, entail collecting feedback from end users, with a particular emphasis on the system's usability, efficiency, and overall user experience. Statistical analysis provides quantitative insights into the performance of the system and identify opportunities for improvement. The emphasis during the evaluation phase collecting valuable user feedback through rigorous testing scenarios. This feedback help us make data-driven system changes. The evaluation method is iterative, allowing us to continuously improve the C-NIOSH-RWL system.

4.2.1 User Tests

Scenario: You are an industrial engineering student who takes the Work Study and Ergonomics course at Bahçeşehir University. You want to calculate the NIOSH recommended weight limit on the RWL calculator website. After entering the multiplier values, you can check the risk implication and recommended actions on the system.

User Demographics:

1. Participant -35 sec – student – 23 years old
2. Participant – 48 sec – student – 24 years old
3. Participant – 64 sec – student- 23 years old
4. Participant – 43 sec – student- 23 years old
5. Participant – 72 sec – student- 21 years old
6. Participant – 29 sec – student - 23 years old
7. Participant – 37 sec – student - 23 years old
8. Participant – 52 sec - student -22 years old
9. Participant – 58 sec - student -20 years old
10. Participant – 42 sec - student -21 years old
11. Participant - 189 sec - real estate agent - 63 years old
12. Participant - 76 sec - real estate agent - 46 years old
13. Participant - 120 sec - real estate agent - 44 years old
14. Participant - 130 sec - real estate agent - 54 years old
15. Participant - 162 sec - real estate agent - 51 years old
16. Participant - 127 sec- real estate agent - 30 years old
17. Participant - 187 sec- real estate agent - 65 years old
18. Participant - 88 sec - student - 22 years old
19. Participant - 65 sec - student - 21 years old
20. Participant - 76 sec - student - 21 years old
21. Participant - 45 sec - student - 23 years old
22. Participant - 56 sec - student - 22 years old
23. Participant - 39 sec - industrial engineer - 23 years old
24. Participant - 46 sec - student - 23 years old
25. Participant - 35 sec - student 23 years old
26. Participant - 42 sec - student 23 years old
27. Participant - 58 sec - student 23 years old
28. Participant - 65 sec - student 22 years old
29. Participant - 70 sec - student 23 years old
30. Participant - 100 sec - student 23 years old

Effects of the UX Problems in the Users:

- Tested users stated that the size of the buttons on the upper left side could be bigger.
- Tested users stated that the system should give an error message when you enter wrong input.
- Tested users informed us that if they could enter input with fractions, it could be more helpful.

Statistical Analysis:

4.2.2 Effectiveness of the system:

Task Completion Rate: Before testing, the Industrial Engineering teams conducted a thorough evaluation of the system and established ideal benchmark criteria. Following these evaluations, benchmark values for evaluation metrics were determined. As part of the Industrial Engineering team's assessment, it was determined that the benchmark should exceed 80%.

Participants	Status
Participant 1	Completed
Participant 2	Completed
Participant 3	Completed
Participant 4	Completed
Participant 5	Completed
Participant 6	Completed
Participant 7	Completed
Participant 8	Completed
Participant 9	Completed
Participant 10	Completed
Participant 11	Completed
Participant 12	Completed
Participant 13	Completed
Participant 14	Completed
Participant 15	Completed
Participant 16	Completed
Participant 17	Completed
Participant 18	Completed
Participant 19	Completed
Participant 20	Completed
Participant 21	Completed
Participant 22	Completed
Participant 23	Completed
Participant 24	Completed
Participant 25	Completed
Participant 26	Completed
Participant 27	Completed
Participant 28	Completed
Participant 29	Completed
Participant 30	Completed

Task Completion Rate	100%

.

$$n_{adj} = n + Z_{\alpha/2}{}^{2}$$

$$\hat{p}_{adj} = \frac{x + \frac{Z_{\alpha/2}{}^{2}}{2}}{n + Z_{\alpha/2}{}^{2}}$$

$$\hat{p}_{adj} = \frac{30 + \frac{(1.96)^2}{2}}{30 + (1.96)^2}$$

$$0.94 - 1.96\sqrt{\frac{0.94(1-0.94)}{33.84}} < p < \quad 0.94 + 1.96\sqrt{\frac{0.94(1-0.94)}{33.84}}$$

$$0.86 < p < 1.02$$

Conclusion: With task completion estimated at over 80% (confidence level 95%), it is determined that the web page is suitable for use.

4.2.3 Efficiency of the system:

Task Completion Duration: Before testing, the Industrial Engineering teams conducted a thorough evaluation of the system and established ideal benchmark criteria. Following these evaluations, benchmark values for evaluation metrics were determined. As the Industrial Engineering team, we defined the benchmark should not exceed 100 seconds.

Participants	Duration
Participant 1	35
Participant 2	48
Participant 3	64
Participant 4	43
Participant 5	72
Participant 6	29
Participant 7	37
Participant 8	52
Participant 9	58
Participant 10	42
Participant 11	189
Participant 12	76
Participant 13	120
Participant 14	130
Participant 15	162
Participant 16	127
Participant 17	187
Participant 18	88
Participant 19	65
Participant 20	76
Participant 21	45
Participant 22	56
Participant 23	39
Participant 24	46
Participant 25	35
Participant 26	42
Participant 27	58
Participant 28	65
Participant 29	70
Participant 30	100
Mean Task Duration:	75,2
Standard Deviation:	44,41528162

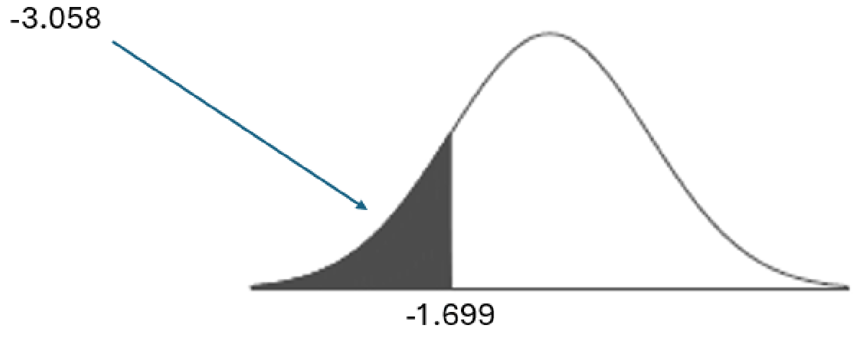
$$H_0 : \mu = \mu_0$$

$$H_1 : \mu < \mu_0$$

$$t = \frac{\bar{X} - \mu_0}{\left(s / \sqrt{n} \right)}$$

$$if \; -t < -t_{n-1,\alpha} \text{ then } H_0 \text{ is rejected.}$$

$$t = \frac{75.2 - 100}{\left(\frac{44.41}{\sqrt{30}} \right)} = -3.058662334$$



$$t_{n-1,0.05} = t_{29,0.05} = 1.699$$

Conclusion: The null hypothesis (H_0) is rejected, indicating that the task completion time is significantly shorter than 100 seconds. Therefore, it can be concluded that the web page provides satisfactory user experience.

4.3.1 T-CSUQ: The test group received the CSUQ questionnaire, which comprises 13 questions, and data were collected accordingly. This questionnaire is divided into four sections: System Usefulness, Information Quality, Interface Quality, and Overall Satisfaction. The first four questions pertain to the System Usefulness followed by three questions assessing Information Quality, another three questions evaluating Interface Quality, and finally, one question addressing Overall Satisfaction.

	Strongly Agree				Strongly Disagree		
	1	2	3	4	5	6	7
1.Overall, I am satisfied with how easy it is to use the system.							
2.It is simple to use this system							
3.I can effectively complete my work using this system							
4.I feel comfortable using this system							
5.It was easy to learn to use this system							
6.I believe I became productive quickly using this system							
7.The system gives error messages that clearly tell me how to fix problems							
8.The information (such as online-help. on screen messages and other documentation) provided with the system is clear							

9.The information provided with the system is easy to understand.							
10. The interface of the system is pleasant.							
11. I like using the interface of this system.							
12.This system has all the functions and capabilities I expect it to have.							
13. Overall. I am satisfied with this system							

USER	1	2	3	4	5	6	SYSUSE	7	8	9	NFOQUAL	10	11	12	NTERQUAL	13
1	3	1	3	4	3	2	**2,8**	3	3	4	**,33333333**	2	2	2	**2**	2
2	2	2	3	2	2	1	**2,2**	1	4	3	**,66666666**	2	2	3	**2,33333333**	1
3	2	2	3	3	3	3	**2,6**	2	2	3	**,33333333**	3	3	2	**2,66666667**	2
4	4	3	3	2	2	2	**2,8**	2	3	2	**,33333333**	4	3	2	**3**	2
5	2	2	1	1	2	2	**1,6**	3	1	3	**,33333333**	2	2	2	**2**	1
6	3	3	3	4	3	2	**3,2**	2	5	3	**,33333333**	2	2	3	**2,33333333**	3
7	2	2	1	1	1	1	**1,4**	3	3	2	**,66666666**	3	3	4	**3,33333333**	2
8	4	4	3	3	3	2	**3,4**	3	4	3	**,33333333**	2	2	3	**2,33333333**	3
9	4	4	3	5	4	3	**4**	4	3	3	**,33333333**	4	4	4	**4**	3
10	3	3	4	4	4	3	**3,6**	3	4	3	**,33333333**	3	3	4	**3,33333333**	3
11	1	1	2	3	2	1	**1,8**	1	1	2	**,33333333**	2	2	1	**1,66666667**	1
12	2	2	3	2	3	3	**2,4**	4	4	3	**,66666666**	2	2	3	**2,33333333**	3
13	1	1	1	2	3	2	**1,6**	3	4	1	**,66666666**	1	4	2	**2,33333333**	2
14	1	1	1	2	1	1	**1,2**	2	2	1	**,66666666**	3	3	1	**2,33333333**	1
15	2	1	2	2	2	1	**1,8**	2	1	1	**,33333333**	1	1	1	**1**	2
16	1	2	1	1	1	2	**1,2**	3	1	1	**,66666666**	1	1	1	**1**	1
17	1	2	2	2	4	2	**2,2**	4	3	2	**3**	2	3	2	**2,33333333**	2
18	1	1	2	1	1	1	**1,2**	2	1	1	**,33333333**	3	3	2	**2,66666667**	1
19	2	1	1	1	2	2	**1,4**	1	1	2	**,33333333**	2	2	1	**1,66666667**	1
20	2	2	1	1	1	1	**1,4**	2	3	3	**,66666666**	1	1	2	**1,33333333**	2
21	1	2	1	2	2	1	**1,6**	3	3	3	**3**	2	2	1	**1,66666667**	1
22	2	2	1	2	3	2	**2**	3	3	3	**3**	2	2	1	**1,66666667**	1
23	3	3	2	2	4	3	**2,8**	4	3	3	**,33333333**	2	2	3	**2,33333333**	2
24	3	3	3	3	3	2	**3**	3	2	4	**3**	3	2	1	**2**	2
25	2	2	1	2	3	3	**2**	3	2	3	**,66666666**	3	2	2	**2,33333333**	2
26	2	3	2	1	1	2	**1,8**	3	4	2	**3**	3	3	2	**2,66666667**	1
27	3	3	2	2	1	2	**2,2**	3	2	4	**3**	2	3	2	**2,33333333**	1
28	2	2	2	3	2	3	**2,2**	2	2	3	**,33333333**	3	2	2	**2,33333333**	2
29	3	2	3	2	2	3	**2,4**	4	2	3	**3**	2	2	2	**2**	1
30	3	3	2	1	2	2	**2,2**	3	2	4	**3**	3	3	1	**2,33333333**	2
MEAN							2,2				**,63333333**				**2,25555556**	1,7666666
Std. Dev							**74648602**				**69673568**				**,647324782**	

After gathering the data, we employed linear regression analysis in statistics to determine the association between each section and the overall value. The Multiple R value should fall between zero and one. A value closer to zero signifies a weaker relationship between the two variables, whereas a value closer to one indicates that the two variables move in the same direction.

4.3.2 SYSUSE - OVERALL

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0,723426374
R Square	0,523345719
Adjusted R Square	0,506322351
Standard Error	0,511461053
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	8,042079208	8,042079	30,742785	6,27447E-06
Residual	28	7,324587459	0,261592		
Total	29	15,36666667			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*.ower 95,0%*	*Jpper 95,0%*
Intercept	0,214686469	0,295072819	0,727571	0,4729166	-0,389742801	0,819116	-0,38974	0,819116
SYSUSE	0,705445545	0,127230692	5,544618	6,2745E-06	0,444825286	0,966066	0,444825	0,966066

The relationship between System Usefulness (SYSUSE) and Overall was determined through regression analysis. In our regression analysis **The Multiple R** value of 0.723 indicates a moderate positive linear relationship between the independent variables. This suggests that there is a correlation between the two variables, but it's not extremely strong.

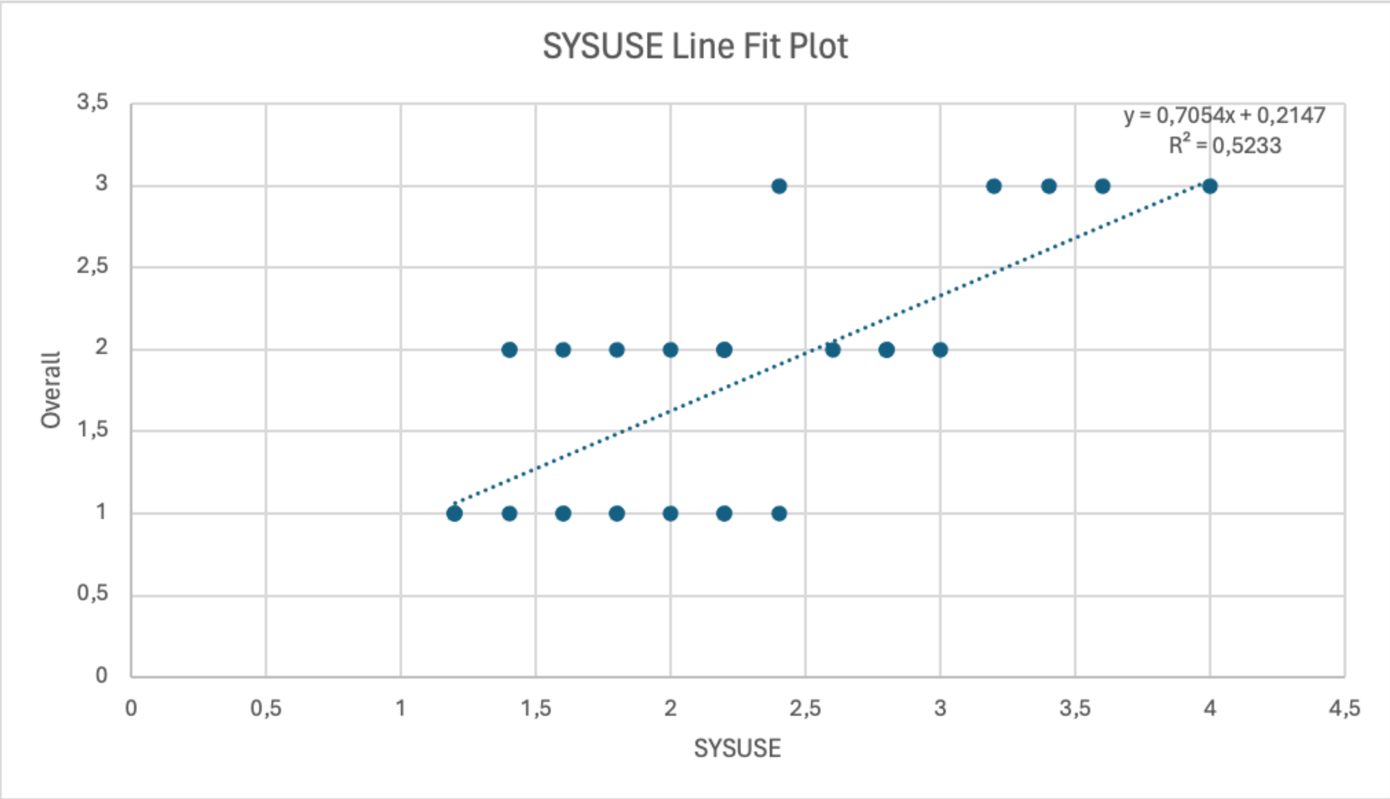
R Square (Coefficient of Determination): The R^2 value of 0.523 means that approximately 52.3% of the variance in the dependent variable can be explained by the independent variable in the model. This indicates a moderate level of goodness of fit, meaning that the model explains a moderate portion of the variability in the dependent variable.

Adjusted R Square: The adjusted R^2 value of 0.506 is similar to the R^2 value but is adjusted for the number of independent variables in the model. It is slightly lower than the R^2 value, suggesting that the model's explanatory power is slightly penalized for having more predictors.

Standard Error: The standard error of approximately 0.511 indicates the average distance that the observed values fall from the regression line. A smaller standard error suggests that the model's predictions are more precise.

The Significance F value serves as a metric of the reliability or statistical significance of your results. If the Significance F value is below 0.05 (5%), it indicates that your model is acceptable. Conversely, if it exceeds 0.05, it suggests considering alternative independent variables.

In our analysis, the F-statistic of 30.74, coupled with a p-value of 0.00000627, underscores the statistical significance of the overall regression model. This suggests that at least one of the independent variables included in the model has a non-zero coefficient.



Overall, the regression analysis suggests that the SYSUSE variable has a statistically significant positive effect on the overall satisfaction.

4.3.3 INFOQUAL - OVERALL

The relationship between Information quality (INFOQUAL) and Overall was determined through regression analysis. In our regression analysis **The Multiple R** value of 0.550 indicates a moderate positive linear relationship between the INFOQUAL variable and the overall value. This suggests that there is a correlation between information quality and the overall satisfaction, but the relationship is not extremely strong.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,550716554							
R Square	0,303288722							
Adjusted R Squa	0,278406177							
Standard Error	0,618354093							
Observations	30							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	4,660536701	4,660537	12,18881408	0,00161275			
Residual	28	10,70612997	0,382362					
Total	29	15,36666667						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0,25151276	0,448430044	0,560874	0,579344592	-0,66705455	1,170080065	-0,66705455	1,170080065
INFOQUAL	0,575374901	0,164804925	3,491248	0,00161275	0,237787315	0,912962488	0,237787315	0,912962488

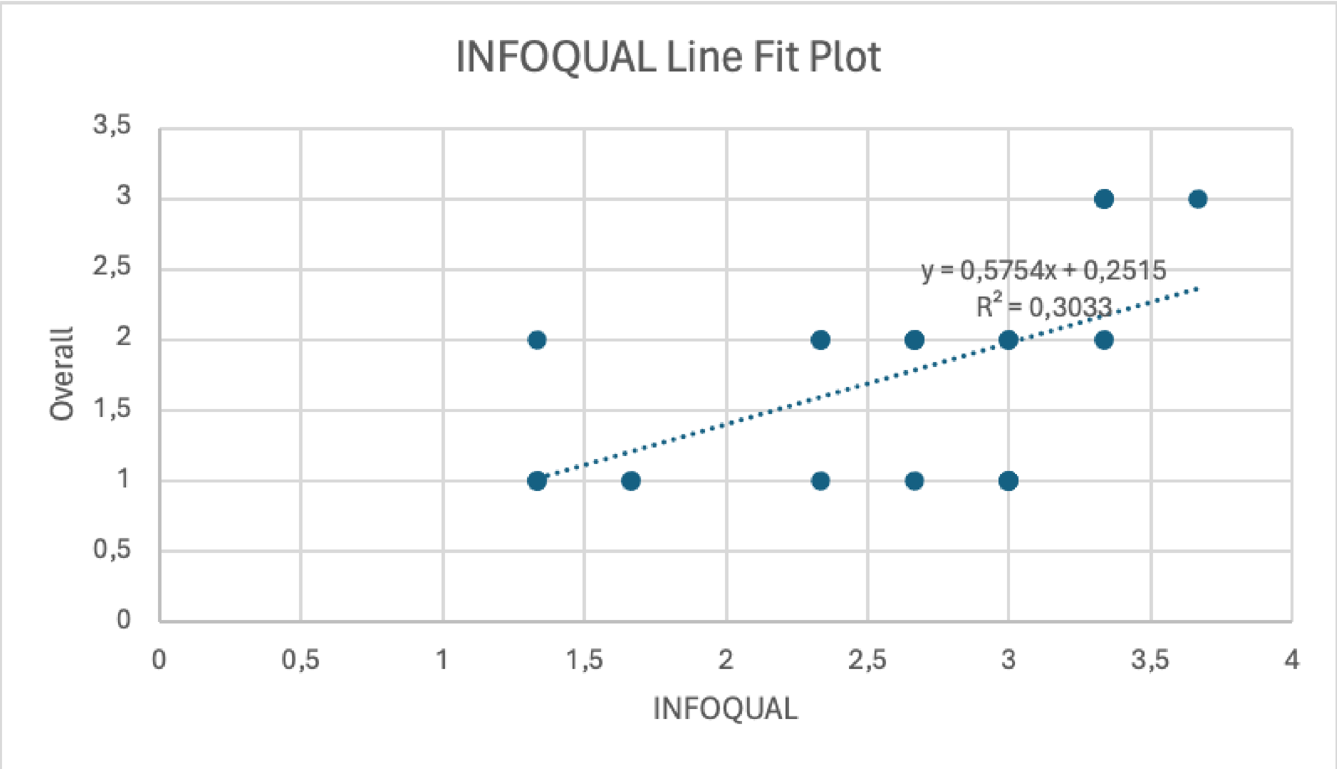
R Square (Coefficient of Determination): The R^2 value of 0.303 means that approximately 30.3% of the variance in the overall value can be explained by the information quality variable in the model. This indicates a moderate level of goodness of fit, suggesting that the model explains a moderate portion of the variability in the overall satisfaction.

Adjusted R Square: The adjusted R^2 value of 0.278 is slightly lower than the R^2 value, indicating that the model's explanatory power is slightly penalized for having more predictors.

Standard Error: The standard error of approximately 0.618 indicates the average distance that the observed values fall from the regression line. A smaller standard error suggests that the model's predictions are more precise.

The Significance F value serves as a metric of the reliability or statistical significance of your results. If the Significance F value is below 0.05 (5%), it indicates that your model is acceptable. Conversely, if it exceeds 0.05, it suggests considering alternative independent variables.

In the context of our analysis, the F-statistic of 12.19, coupled with a p-value of 0.00161, demonstrates that the overall regression model holds statistical significance. This finding implies that the information quality variable significantly influences the overall value.



Overall, the regression analysis suggests that the information quality variable has a statistically significant positive effect on the overall satisfaction.

4.3.4 INTERQUAL - OVERALL

The relationship between Interface Quality (INTERQUAL) and Overall was determined through regression analysis. In our regression analysis **The Multiple R** value of 0.448 indicates a moderate positive linear relationship between the INTERQUAL variable and the overall value. This suggests that there is a correlation between interface quality and the overall satisfaction, but the relationship is not extremely strong.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,448020639
R Square	0,200722493
Adjusted R	0,172176868
Standard E	0,662307412
Observatio	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3,08443564	3,084436	7,031638	0,013034653
Residual	28	12,28223103	0,438651		
Total	29	15,36666667			

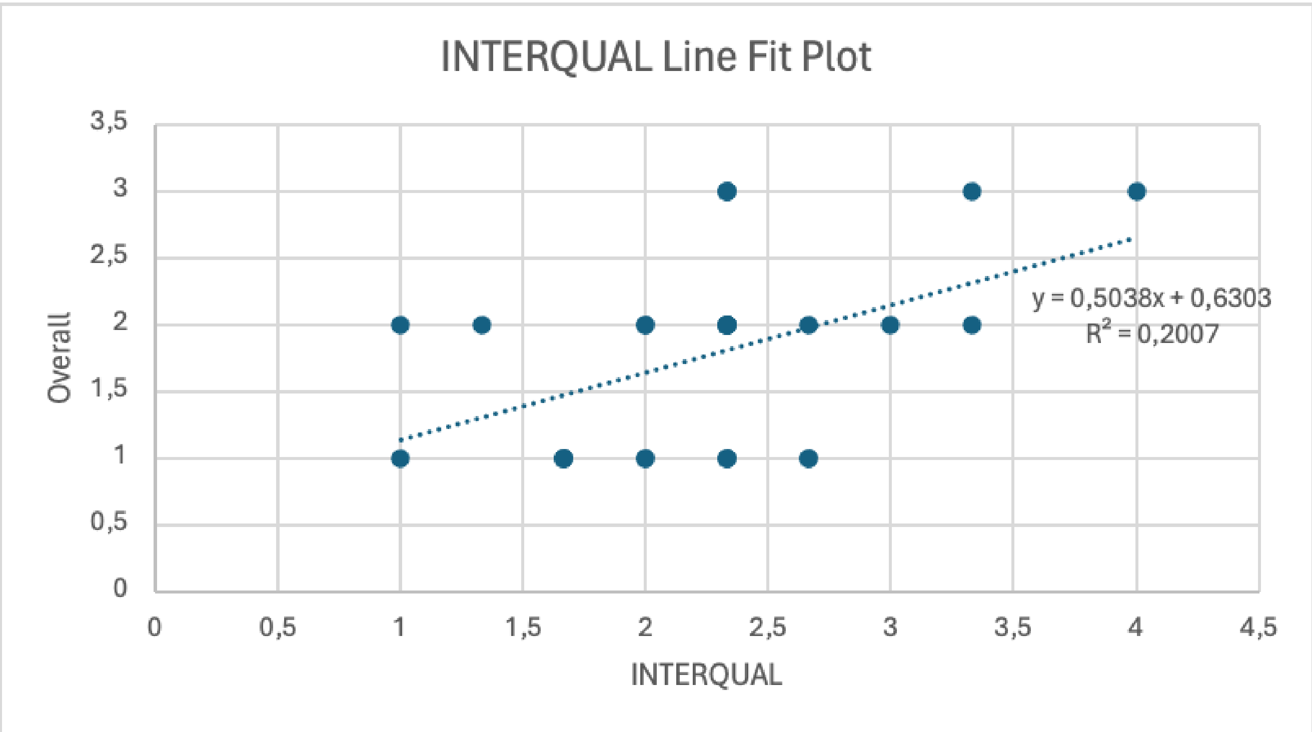
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0,630295642	0,445273732	1,415524	0,167942	-0,281806251	1,542398	-0,281806251	1,542397535
INTERQUAL	0,503809814	0,189993342	2,651724	0,013035	0,114626095	0,892994	0,114626095	0,892993533

R Square (Coefficient of Determination): The R^2 value of 0.201 means that approximately 20.1% of the variance in the overall value can be explained by the interface quality variable in the model. This indicates a moderate level of goodness of fit, suggesting that the model explains a moderate portion of the variability in the overall satisfaction.

Adjusted R Square: The adjusted R^2 value of 0.172 is slightly lower than the R^2 value, indicating that the model's explanatory power is slightly penalized for having more predictors.

Standard Error: The standard error of approximately 0.662 indicates the average distance that the observed values fall from the regression line. A smaller standard error suggests that the model's predictions are more precise.

In our analysis, the F-statistic of 7.03, coupled with a p-value of 0.0130, highlights the statistical significance of the overall regression model. This implies that the interface quality variable holds a significant effect on the overall value.



Overall, the regression analysis suggests that the interface quality variable has a statistically significant positive effect on the overall satisfaction.

The Multiple R values obtained after regression analysis are as follows:

Sysuse-Overall = 0.72
Infoqual-Overall = 0.55
Interqual-Overall = 0.45

As the Multiple R value approaches 1, the level of relationship becomes stronger. In this case; Sysuse, Infoqual, Interqual are determined to have a higher relationship with Overall, respectively.

From a UX standpoint, enhancing all three aspects could enhance user satisfaction. However, if resources are constrained, prioritizing improvements in system usefulness would be most beneficial.

4.4.1 Heuristic Evaluation

User Control and Freedom: The system implements a "Home" button prominently positioned on the results page, affording users the flexibility to navigate between pages solely without relying on the browser's back button. By providing this intuitive navigation feature, users feel in control of their interactions with the system, thereby enhancing their overall user experience.

Aesthetic and Minimalist Design: The system's design ethos follows a minimalist approach, prioritizing simplicity, and clarity to streamline the user interface. By minimizing visual clutter and extraneous elements, such as unnecessary graphics or text, the system ensures that users can focus solely on the essential components relevant to their task. This minimalist design not only enhances the visual appeal of the interface but also facilitates ease of use and navigation, ultimately contributing to a more enjoyable and efficient user experience.

Help and Documentation: The system goes beyond basic functionality by providing comprehensive help and documentation resources for users. This includes educational videos and written guides detailing the principles and guidelines of NIOSH RWL. By offering multiple formats of instructional materials, the system caters to diverse learning preferences and levels of expertise among users. Additionally, contact numbers are readily accessible for users seeking further assistance or clarification, ensuring that users feel supported and confident in their interactions with the system. Overall, these proactive measures to provide help and documentation contribute to a more user-friendly and inclusive experience.

5. SUMMARY AND CONCLUSION

In this project, we developed a robust software system designed to calculate the NIOSH Recommended Weight Limits (RWL) to enhance workplace safety and ergonomics. The system is intended for educational purposes, specifically for industrial engineering students in Work Study and Ergonomics classes. It incorporates comprehensive algorithms aligned with NIOSH guidelines, enabling precise calculations of safe lifting weights based on various parameters such as load weight, frequency, duration, and environmental factors. During development, we ensured the system has an intuitive user interface for easy data input and clear result visualization.

The RWL calculator was tested on 30 participants, primarily students. At the beginning of the tests, participants were given a scenario. In this scenario, participants were asked to calculate the RWL according to the input provided by our industrial engineering team, and then analyze the results and recommendations.

Based on the industrial engineering team’s assessment, it was determined that the task completion benchmark should exceed 80% and not exceed 100 seconds. Participants successfully completed the test without any assistance. According to the T-CSUQ questionnaire and positive feedback received from participants, the system’s usability, accuracy, and reliability were confirmed.

In summary, we have developed a website that students can use in the Work Study and Ergonomics course to make RWL calculations. We tested this website, and based on the evaluations of the test results, we have presented a successful project.

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APPENDIX A

GITHUB CODE:

https://github.com/Wermat159/rwl-niosh