PRESIDENCY UNIVERSITY
Private University Estd. in Karnataka State by Act No. 41 of 2013
Itgalpura, Rajankunte, Yelahanka, Bengaluru – 560064

USE OF DIGITAL TECHNOLOGY TO CALCULATE WATER FOOTPRINTS FOR DIFFERENT DAILY USE ITEMS

A PROJECT REPORT

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BACHELOR OF TECHNOLOGY

IN

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PRESIDENCY SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

BONAFIDE CERTIFICATE

Certified that this report "USE OF DIGITAL TECHNOLOGY TO CALCULATE WATER FOOT PRINTS FOR DIFFERENT DAILY USE ITEMS" is a Bonafide work of "GALIJARLA VEDIKA VARMA (20221CSD0011), AMMINENI PRANAVI (20221CSD0057)", who have successfully carried out the project work and submitted the report for partial fulfilment of the requirements for the award of the degree of BACHELOR OF TECHNOLOGY in COMPUTER SCIENCE ENGINEERING (DATA SCIENCE) during 2025-26.

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DECLARATION

We the students of final year B.Tech in COMPUTER SCIENCE ENGINEERING, DATA SCIENCE at Presidency University, Bengaluru, named GALIJARLA VEDIKA VARMA, AMMINENI PRANAVI hereby declare that the project work titled "USE OF DIGITAL TECHNOLOGY TO CALCULATE WATER FOOTPRINTS FOR DIFFERENT DAILY USE ITEMS" has been independently carried out by us and submitted in partial fulfillment for the award of the degree of B.Tech in COMPUTER SCIENCE ENGINEERING (DATA SCIENCE) during the academic year of 2025-26. Further, the matter embodied in the project has not been submitted previously by anybody for the award of any Degree or Diploma to any other institution.

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Abstract

Freshwater is the most finite of renewable resources, yet its use is often invisible to the people and industries that depend on it. Modern consumption patterns - from the food we eat to the clothes we wear - carry a "hidden" water cost that rarely appears on a bill or in a supply-chain dashboard. This project, Digital Water Footprint Calculator, responds to that gap by building a practical tool that allows individuals to estimate and track the water embodied in their daily choices.

The core concept is straightforward: a user photographs or selects a common item say, a cup of coffee, a kilogram of rice, or a cotton T-shirt and receives an estimate of the total freshwater consumed across that item's life cycle. Behind that simple interaction sits a structured architecture combining client-side image capture, a curated database of product-specific water-use coefficients, and an optional machine-learning model for automatic item recognition.

From a technical perspective, the application employs a React and TypeScript front end compiled with Vite for fast development and Progressive Web App capabilities. Camera access is provided through modern browser APIs with a graceful fallback to manual image upload. The water-coefficient dataset - covering staples such as grains, vegetables, textiles, and selected manufactured goods - is stored locally in JSON format and periodically refreshed from authoritative research sources.

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Abbreviations

Abbreviation	Full Form
AI	Artificial Intelligence
IoT	Internet of Things
SDG	Sustainable Development Goal
UN	United Nations
UI	User Interface
GUI	Graphical User Interface
PC	Personal Computer
GB	Gigabyte
API	Application Programming Interface
RAM	Random Access Memory
DB	Database
SQL	Structured Query Language
WFN	Water Footprint Network
FAO	Food and Agriculture Organization
UNESCO	United Nations Educational, Scientific and Cultural Organization
HTTP	HyperText Transfer Protocol
REST	Representational State Transfer
JSON	JavaScript Object Notation
PWA	Progressive Web App
ISO	International Organization for Standardization
TLS	Transport Layer Security
SSD	Solid State Drive
TP	Test Point

Chapter 1
Introduction

Water is one of the most critical natural resources that sustains life, economic development, and ecological balance. Rapid population growth, urbanization, and increased consumption patterns have put immense pressure on freshwater supplies around the world. Many people are unaware of the amount of water that is used-both directly and indirectly-in day-to-day life and products. This hidden or "virtual" water use is represented by the concept of a water footprint, which quantifies the total volume of freshwater that is used to produce certain goods and services consumed in daily life.
In today's age of digital transformation, technology can significantly contribute toward better environmental monitoring and sustainable resource management. Current modern digital solutions include mobile applications, cloud-based systems, IoT sensors, and data analytics platforms, which altogether provide precise, real-time evaluations of water usage by items and activities.

1.1 Background

In most parts of the world, freshwater resources are under increased stress due to increasing demand, climate change, industrial expansion, and unsustainable consumption habits. Whereas people conventionally think that water is used mainly for obvious activities such as drinking, bathing, or cooking, by far the largest part of water is used indirectly in the production of everyday goods. This indirect use, now termed virtual water, forms a major part of an individual's total water footprint.

Traditionally, water footprint calculation involves labor - intensive data collection, intricate estimation methodologies, and specialized databases. All this has made the process complicated for students, consumers, and even organizations interested in monitoring their water usages. However, rapid growth in digital technologies has opened up new avenues for simplifying and automating such calculations.

Considering both the urgent need for sustainable resource management and increasing accessibility to digital innovations, there is an evident need for technology-based approaches in understanding and minimizing water footprints. This project leverages the advantages of digital advancements to estimate the water footprint of several items of everyday use and critically analyze them for better awareness and the adoption of improved water usage habits.

1.2 Statistics

The global availability of water is extremely limited; only about 2.5% of Earth's water exists as freshwater, and less than 1% is accessible for human use. Due to the surge in population and increasing consumption, the global demand for freshwater has increased by nearly 600% in the last hundred years and is further expected to increase another 20–30% by 2050.

Currently, nearly 4 billion people experience high water scarcity for at least one month per year, underlining the urgent need for better monitoring and conservation. The water footprint of many common daily items reflects more adequately the hidden water cost buried within everyday life: a cup of coffee represents about 140 liters of water, while making a cotton T-shirt requires nearly 2,700 liters.

Accordingly, manufacturing one pair of jeans requires about 10,000 liters of water, and even producing a smartphone can require up to 4,000 liters. Household usage also accounts for a big share of water: an average urban person uses 150–200 liters daily for bathing, cleaning, and washing.

Digital technologies therefore have an increasingly important role to play in mitigating these challenges, given that IoT-based water sensors can prevent waste by 20–40%, smart meters give up to 98% accurate real-time data, and AI-driven systems improve leaks and optimize usage, thereby saving up to 30% more water. Jointly, these statistics foreground the importance of digital solutions that help determine and decrease the water footprint of daily-use items and create in effect more sustainable patterns of consumption.

1.3 Prior existing technologies

Before the development of advanced digital systems, water footprint assessment was primarily carried out with manual calculations, standardized formulas, and publicly available datasets. Traditional approaches were largely paper-based, while early methods depended on aggregated global averages published by organizations such as the WFN and UNESCO.

One of the first digital methods involved online calculators with static data repositories. These are web tools where a user selects products from a fixed list and gets an approximate water footprint based on world statistics. While these were accessible to users, they could not adapt the calculation to local conditions, specific manufacturing settings, or personal consumption patterns.

As technology developed, water footprint databases started to be integrated into mobile applications, thus allowing for more interactive interfaces. Examples include Water Footprint Calculator, which introduced household surveys, lifestyle questionnaires, and basic analytics. These platforms were still dependent on general datasets and could not measure data in real time.

Accordingly, water meters and sensors based on IoT have been implemented in industries and agriculture to measure the direct consumption of water. Such devices enabled the continuous measurement of water flow, leakage detection, and tracking of efficiency. Although they were highly effective in managing physical water consumption, they did not calculate the virtual water footprint of any product directly.

1.4 Proposed approach

1.4.1 Aim of the Project

The aim of this project is to design a user-friendly, digital system through which standardized datasets are integrated with modern digital technologies to accurately calculate and present the water footprints of different items of everyday use. This project aims to provide an easily accessible platform that raises awareness about virtual water consumption, enables better decision-making, and facilitates sustainable use of fresh water based on insights driven by data.

1.4.2 Motivation

The study of virtual water and the amount of freshwater used to produce everyday items is essential in light of increasing stress on global freshwater resources and the rapid rise in consumption patterns. People are generally unaware of the notion of virtual water and the quantity of freshwater used to produce common items such as clothes, electronics, food items, and household essentials. This is one of the reasons for unsustainable usage and increased water scarcity. This project was motivated by the need to fill this knowledge gap through the use of modern digital technology to present water footprint information in an accessible, accurate, and relevant manner.

1.4.3 Proposed Approach

The idea behind this project is to make people more aware of how much water is hidden in the everyday products they use. To achieve this, the proposed approach focuses on creating a simple and interactive digital tool that anyone can use. The first step is to gather reliable water-footprint information from trusted sources and organize it into a clean digital database. This ensures that the information displayed to users is accurate and meaningful.

To make the tool more personal, users may also be able to enter their usage habits, which will help the system give customized insights on how much water they indirectly consume. The final goal of the approach is not just to calculate numbers but to inspire people to make more sustainable decisions. By using digital technology to explain water footprints in a simple and relatable manner, this project aims to create awareness and encourage positive change in everyday life.

1.4.4 Applications of the Project

This project can be used in many practical and meaningful ways to help people understand and reduce their hidden water consumption.

1. Awareness for the Public
2. Better Household Decisions
3. Support for Environmental Campaigns
4. Guidance for Small Businesses
5. Personal Water Tracking
6. Encouraging Sustainable Living

1.4.5 Limitations of the Proposed Approach

- Dependent on Existing Data
- Complex Supply Chains
- Limited Product Database
- Internet Dependency
- Indirect Water Usage Complexity
- User Engagement Required
- Dynamic Changes in Water Footprints

1.5 Objectives

- To help people understand their hidden water usage by showing how much water is required to produce everyday items.
- To create a simple digital tool that anyone can use without technical knowledge.
- To present water footprint data in an easy and visual way, using charts, comparisons, and short explanations.
- To encourage more responsible and eco-friendly choices by making users aware of the impact of their daily habits.
- To build a reliable database of water footprint values collected from trusted global sources.
- To allow users to compare different products and choose options that save more water.

1.6 SDGs

This project aligns with the following Sustainable Development Goals (SDGs):

- SDG 6 – Clean Water and Sanitation: Supports efficient use of water by calculating water footprints and helps reduce freshwater wastage unnecessarily during day-to-day activities.
- SDG 9 – Industry, Innovation and Infrastructure: Uses digital technologies-apps, sensors, and analytics-for the calculation of water footprints. Enhances innovation by implementing smart tools for resource monitoring.
- SDG 11 – Sustainable Cities and Communities: Assists communities in adopting smart and efficient methods of water management. Supports building eco-friendly, resource-efficient urban environments.
- SDG 12 – Responsible Consumption and Production: Promotes sustainable choices by bringing attention to hidden water consumption. Encourages the mindful use of products that have less environmental impact.
- SDG 13 – Climate Action: Reduces environmental impact by encouraging water conservation. Water-saving habits relieve stress on climate-affected water resources.

Fig 1.1 Sustainable development goals

1.7 Overview of project report

This project report is organized into eight chapters, each designed to clearly present the journey from the problem background to the final outcomes and supporting materials.

- Chapter 1 introduces the project by giving background information, the purpose of the project and why it is needed, gives important statistics, describes existing technologies, our proposed solution, project objectives, and how it connects to UN Sustainable Development Goals.
- Chapter 2 presents a review of the related research papers and existing tools on AI-based plant disease detection and mobile farming apps created by other people.
- Chapter 3 describes how the system works, from its design to collecting data, training an AI model, to step-by-step procedures of how everything functions as a whole.
- Chapter 4 describes the hardware and software required, the tools that were used to construct the system, and the setup's technical details.
- Chapter 5 discusses the results of our project: the performance of the AI model, accuracy levels, and examples of the outputs from the system.
- Chapter 6 describes the deployment of the app and testing done to ensure that the system works reliably and correctly.

- The main results are summarized in Chapter 7, along with the achievements concerning the project and ideas about future improvements.
- Chapter 8 enumerates all the references we used and attaches appendices with supporting materials: extra data, code samples, and additional documents related to the project.

Chapter-2
Literature review

The idea of measuring the water embedded in products often called the water footprint or virtual water started as a way to make invisible water costs visible. Early research showed that everyday items like food, clothing, and electronics require far more water than most people imagine, and that focusing only on direct household use misses the larger picture.

Researchers quickly developed methods to break down water footprints into different components typically called blue, green, and grey water to describe irrigation/withdrawn water, rainwater used by crops, and the water needed to dilute pollution, respectively. This classification made it easier to compare products and to identify which parts of a product's life cycle use the most water.

As data and computing power improved, several online calculators and public databases emerged that let people estimate footprints using average values. These tools made the idea more accessible but had limits: they often used global averages that didn't reflect local farming methods, production efficiencies, or supply-chain differences. Scholars noted that while such tools are excellent for raising awareness, they were less reliable for precise, location-specific audits.

More recently, the literature has focused on digitizing and automating water-footprint estimation. Studies highlight how IoT sensors, smart meters, and remote monitoring systems have improved the accuracy of measuring *direct* water flows in homes and industries. At the same time, cloud computing and big-data platforms have enabled the aggregation of production and environmental data across regions, allowing for more refined *indirect* water estimates. Researchers point out that integrating real-time sensor data with lifecycle databases can bridge the gap between rough estimates and context-sensitive results.

A recurring theme is usability and communication: several studies stress that technical accuracy alone is not enough. For digital tools to change behaviour, results must be presented in relatable ways simple visuals, comparisons, and actionable tips. This has inspired human-centred design approaches that combine robust back-end calculations with friendly front-end displays for non-expert users.

Finally, the literature consistently flags limitations and research needs: better local data, more transparent models, standards for combining sensor data with lifecycle information, and methods for accounting for variable factors like climate, technology changes, and trade. Many authors recommend hybrid systems that use available sensor measurements for direct use and modeled estimates for embedded water a pragmatic approach that balances feasibility and accuracy.

Summary of Literatures reviewed

S#	Article Title, Year, Journal	Methods Used	Key Features	Domerits
1	Water Footprint Assessment Manual 2011, Water Footprint Network	Standard water footprint accountang	Define blue. green and grey footprints	Complex for normal users not digital-triendly
2	Global Water Footprint of Consumption, 2014	Data modelling calculation formulatas	Good source of average waterprints	Not compreho f average water footprint values
3	Digital Tools for Sustainability Tracking, 2019, Sustain	Web dashboards digital calculators	Track resource consumption plaus	User-friendly dashboard, real-time tracking
4	Water Footprint Calculator by GRACE (Online tool), 2018)	Web-based question-naire, database lookup	Helps users estimate household water	Simple, fast, publicly accessible
5	IoT for Smart Water Monitoring 2020, Sensors Journal	IoT sensors cloud analytics	Track real-time water usage in ho	Accurate measurment of direct water use
6	Life Cycle Assessment (LCA) for Product Water Footprint, 2017	LCA water footprorint madels	Calculates water usage foroouct life	Very technical, hard to understand for normal us-
7	Mobile Apps for Sustainable Living 2021, IEEE Access	Moblie app developm-ent awareness tools	Apps that show eco-scores of proucts	Limited coverage of water footprint data
8	AI-Driven Environmental Impact Estimation, 2022	Machine learning dataset mapping	Predict environment impact from known	Needs large datasets, accuracy varies

Fig 2.1 Summary of Literature reviews

Chapter-3
Methodology

The V-Model was selected as the development methodology because it provides a clearly structured, step-by-step process where each development phase on the left side of the 'V' is matched with a corresponding testing phase on the right side. This ensures that the final system is reliable, accurate, user-friendly, and aligned with the core objective of promoting water awareness through technology.

The V-Model helps maintain strong traceability between what we plan and what we finally deliver. Since our project deals with displaying scientific data (water footprint values), the V-Model helps ensure the content and the application are both *consistent*, *verified*, and *validated* at every stage.

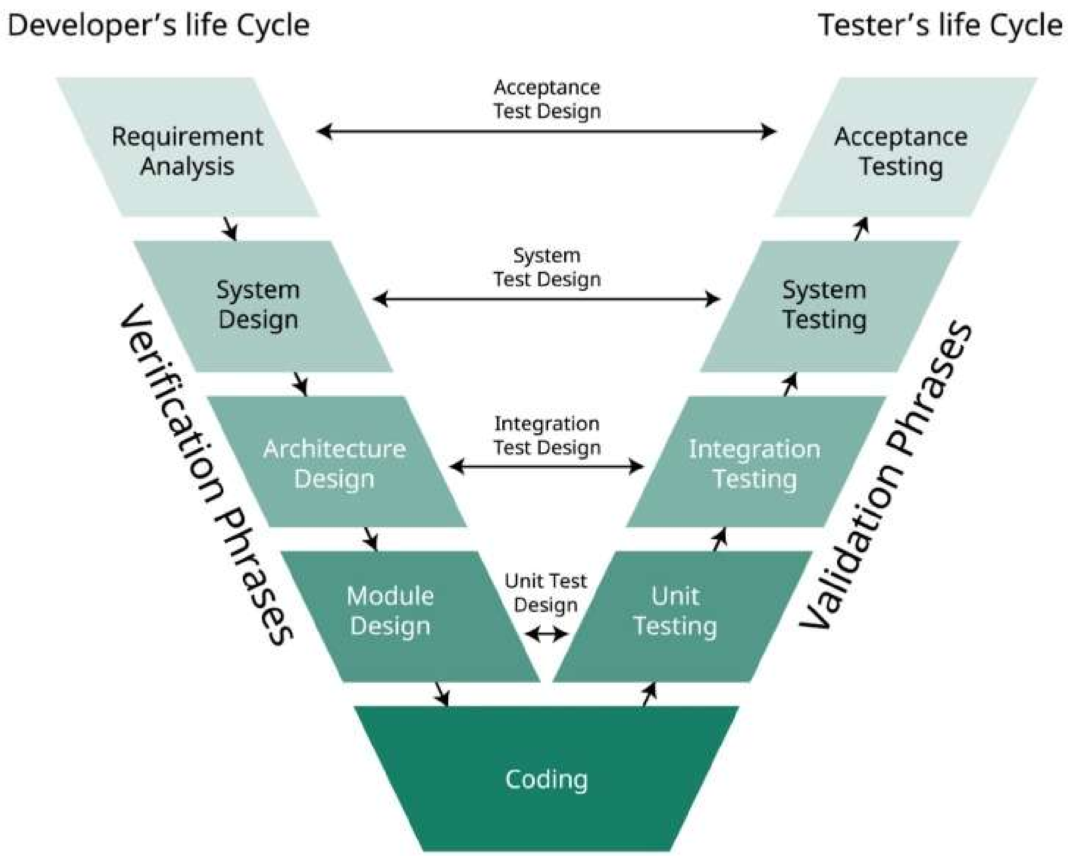


Fig 3.1 The V model methodology

According to Figure 3.1, the V-model connects each development phase with a corresponding testing phase. The verification part consists of requirement analysis, system design, and module design that check whether the system is properly planned. The validation part comprises unit testing, integration testing, system testing, and acceptance testing that verify whether each part of the system is functioning correctly and is in line with the initial requirements. This results in a trustworthy and thoroughly-calculated water footprints.

3.2 Project Stages Mapped to V-Model

3.2.1 Requirements Analysis

This is the foundation of the project. At this stage, we focused on identifying what users truly need from a digital water footprint tool.
Key requirements finalized were:

- The system must allow users to search for any common daily-use item (e.g., milk, cotton T-shirt, rice, eggs).
- The system should display accurate water footprint values from reliable sources.
- It must provide easy comparisons (e.g., “equivalent to 5 buckets of water”).
- The interface should be simple, visually understandable, and accessible to all age groups.
- The tool should aim to increase awareness about water conservation.

This stage clearly defined the purpose, scope, and boundaries of the project.

3.2.2 System Design

Once the requirements were clear, the next step was planning how the system will work.
We designed:

- A central dataset of water footprint values
- A data processing and calculation module
- A search and filter system
- A visual output system for showing charts and comparisons
- Optional features like ranking items by footprint or showing alternatives

This level of design gave us a complete picture of the total system and its key components.

3.2.4 Unit Design

Unit Design is the stage where each individual component of the system is planned in detail before coding begins. Instead of building the entire project at once, we break it down into smaller, manageable units. Each unit focuses on one specific task, making development simpler, cleaner, and easier to test.

For this project, Unit Design plays a crucial role because the system depends on accurate calculations, smooth data flow, and user-friendly interactions. By designing each unit separately, we ensure every part works correctly on its own before being integrated into the larger system.

In this project, the main units designed include:

- Input Unit (User Interaction Module)
- Water Footprint Database Unit
- Calculation Processing Unit
- Output & Visualization Unit
- Recommendation Unit
- Error Handling Unit

Unit Design is like creating small, clearly defined building blocks for the project. Each block has a purpose, a process, and a clear role. When all units work well individually, the entire water footprint calculation system becomes accurate, stable, and user-friendly.

3.3 Verification & Validation Stages

In the V-Model, the Verification and Validation stages ensure that every part of the project from the idea to the final digital tool—works exactly the way it is supposed to. For this water-footprint project, verification helps us check whether we are building the solution *correctly* at each phase, ensuring accuracy of formulas, database structures, user flows, and UI design. Validation, on the other hand, checks whether we have built the *right* solution that real users can trust, understand, and use comfortably. Together, these two stages ensure that the digital tool is not only technically sound but also meaningful, accurate, and impactful for everyday users who want to understand their water consumption better.

3.3.1 Unit Testing

Unit Testing is the stage where each small part of the project is tested individually to make sure it works correctly before connecting it with other modules.

This helps us catch mistakes early, avoid bigger problems later, and ensure every component behaves exactly as expected. For a project that calculates water footprints, unit testing is important because even a small error in formulas or data retrieval can lead to incorrect outputs, which directly affects user trust and system accuracy. Unit testing ensures every building block of the system is reliable and ready for integration.

3.3.2 Integration Testing

The modules are combined, and we check if they communicate properly.
For this project, integration testing verifies that:

- User inputs flow correctly into the calculation engine
- Calculated results are passed to the reporting module
- The database values load at the right time
- All parts behave consistently

This ensures the complete system behaves like one unit, not scattered pieces.

3.3.3 System Testing

we test the complete application from start to finish, just like a real user would. We check:

- Speed
- Responsiveness
- Accuracy
- User experience
- Compatibility across devices

It helps confirm that the project is ready for real-world use.

3.3.4 Validation

Validation ensures that the final system truly meets the needs of real users and performs correctly in real-life situations. While verification checks whether we built the system correctly, validation checks whether we built the *right* system. For a water-footprint calculation project, validation is especially important because users depend on the tool for accurate results and easy-to-understand insights about their daily water consumption.

Through validation, we test the complete system with real data, actual users, and real-world scenarios to ensure the tool is useful, reliable, user-friendly, and capable of helping people make informed decisions about their water usage.

Chapter-4
Project Management

4.1 Project timeline

A structured project timeline was essential to ensure that the development of the digital water footprint calculation system progressed smoothly and was completed within the academic schedule. The project was planned across 13 weeks, divided into well-defined stages that allowed systematic execution and continual refinement. Each phase was aligned with clear goals, expected outcomes, and review checkpoints with the guide.

The timeline began with fundamental research to build a strong knowledge base. Once the theoretical understanding around water footprint concepts and digital estimation techniques was established, the work shifted to requirement analysis and architectural planning.

The middle portion of the timeline focused on software implementation and interface development, which required active collaboration and iterative testing. The final weeks were dedicated to evaluation, improvements, documentation, and presentation preparation.

Table 4.1 Project Timeline Table

Project Phase / Activity	**Description**	**Duration**	**Week Range**
Literature Survey & Concept Study	Understanding water footprint metrics, research papers, and digital tools	2 weeks	Week 1–2
Requirement Analysis	Identifying datasets, parameters, software needs, and defining problem scope	1 week	Week 3
System Architecture & Design	Designing framework, choosing methods, creating workflow models & UI sketches	2 weeks	Week 4–5
Development of Calculation Module	Implementing algorithms for water footprint estimation, testing logic	3 weeks	Week 6–8
Digital Interface & Integration	Designing user interface and integrating calculations into the front-end display	1 week	Week 9
System Testing & Validation	Verifying accuracy, debugging, refining performance based on review feedback	2 weeks	Week 10–11

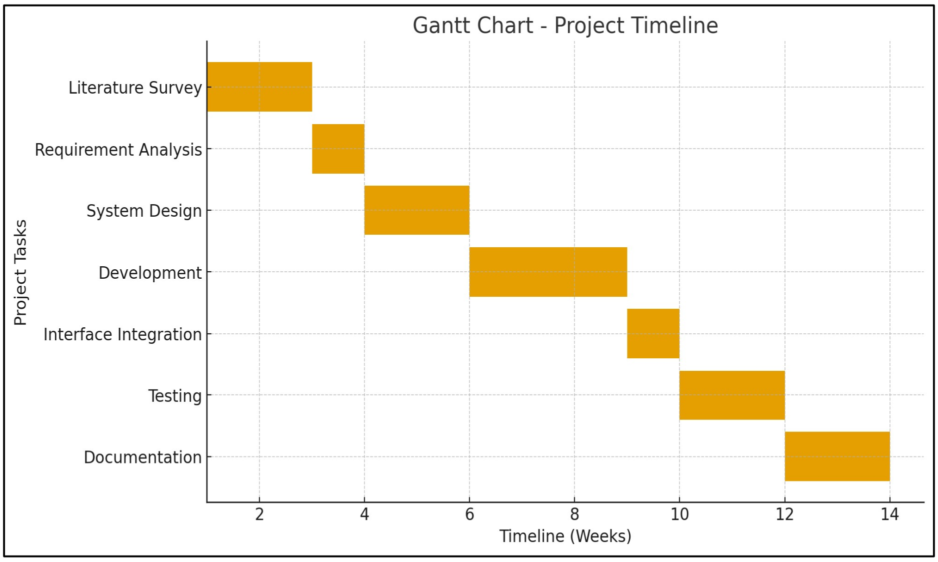


Fig.4.1 Gantt Chart – Project Timeline

Project Planning

Project planning served as the backbone of the entire project. It ensured smooth workflow, prevented confusion, supported teamwork, and enabled us to complete the project within the academic timeframe. Without this structured planning, managing tasks, resources, and time would have been significantly more difficult. The planning phase not only guided our technical progress but also improved coordination and decision-making throughout the development process.

Table 4.2. Project Planning Table

Planning Component	**Description**	**Purpose / Expected Output**
Problem Identification	Understanding the need for calculating water footprints and exploring sustainability importance	Clear recognition of project relevance and goals
Requirement Gathering	Collecting requirements such as datasets, tools, methodologies, and user expectations	List of functional and non-functional requirements
Feasibility & Scope Definition	Evaluating technical, time, and resource feasibility	Defined project boundaries and achievable objectives
Task Breakdown & Work Division	Dividing project into phases: research, design, development, testing, documentation	Work Breakdown Structure (WBS) for clarity and organization
Scheduling & Timeline Planning	Estimating task duration and arranging in weekly Gantt format	Structured timeline to ensure on-time completion

Resource Allocation	Assigning software tools, data sources, roles, and supporting resources	Optimal use of available resources and role clarity
Risk Forecasting & Mitigation	Identifying possible risks such as data inaccuracy or delays	Prevention strategies and contingency actions
Communication & Review Plan	Conducting weekly meetings and guide reviews	Continuous feedback and quality improvement
Expected Deliverables	Prototype digital system, evaluation results, final report	Successful implementation and readable outputs

Table 4.3 Project Planning Timeline

Major Task	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Project initiation (i)	■														
Selection of topic	■	■	■												
Background (ii)		■	■												
Objectives (iii)		■	■	■											
Methodology (iv)			■	■											
Proposal			■	■	■										
Literature review (v)				■	■	■	■								
Design and Ananlysis					■	■	■	■							
System Requirement Phase (vi)					■	■	■	■							
System design phase (vii)						■	■	■	■						
Functional unit design phase (viii)							■	■	■	■					
Report								■	■	■	■				
Final report											■	■	■		

(i) Project initiation - Live Projects, Projects of national importance (Smart - Environment, Mobility, Governance, Building and living, People, Economy, Renewal energy, Water conservation, Waste management, Health, Education, Tourism, Irrigation, Cities), Area for projects (Communication, Embedded systems, Signal and Image processing, VLSI, Controls, Networking, Security and cryptography)

(ii) Background - Background, approach, expected results

(iii) Objectives - Statements that describe the elements to achieve project aim. Writing an objective that is SMART - Specific, Measurable, Attainable/Achievable, Realistic, and Time-bound.

(iv) Methodology - Enlist and briefly describe the different methodology. Briefly describe each stage of the applied methodology , but discuss in details relating the various stages to implement the project.

(v) Literature review - Include a brief description with appropriate illustrations. Discuss the concepts, approach, methods, analysis, and issues adopted in part or full of your approach. Identify inconsistencies, gaps and contradictions, differences. Suggest improvements

(vi) System Requirement Phase - Datasheets, Identifying initial conditions, Identifying input parameters, Identifying system outcomes, Identifying relations, Identifying system constraints

(vii) System design phase - determining functional blocks, Identifying process flow, Identifying inconsistencies, Identifying interfaces, System design and analysis, developing a integrated test plan

(viii) Functional unit design phase - Identifying components, component datasheets, compare components, Unit design and analysis, developing a unit test plan

Project Implementation

To ensure accuracy and manage complexity, the project was implemented using a modular development approach, where independent components were built, tested, and combined sequentially. This helped isolate errors early and improve efficiency

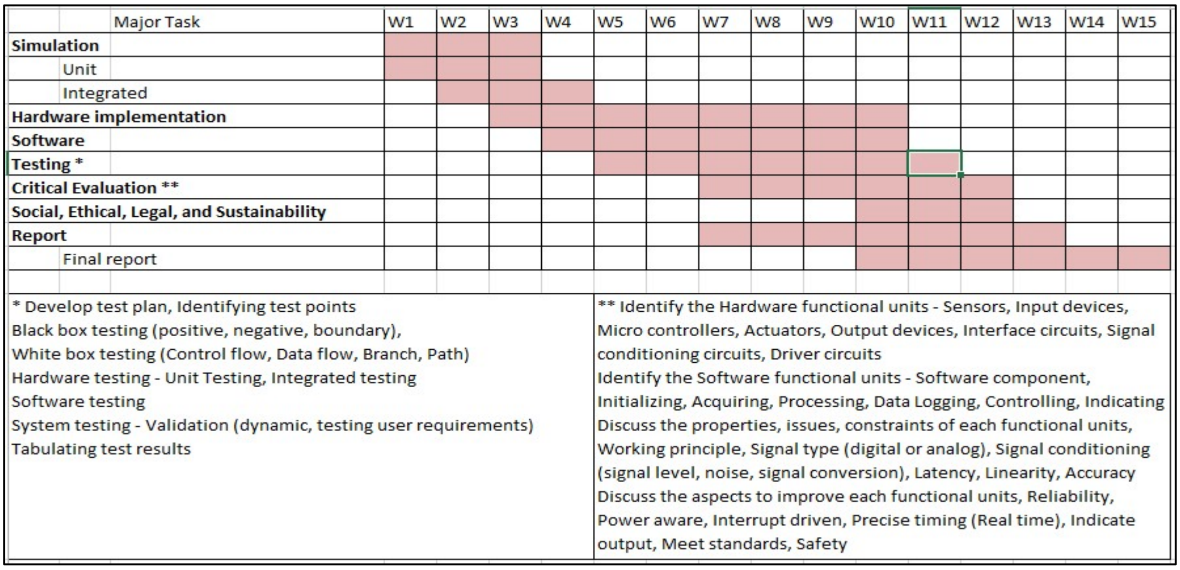
The major stages of implementation included:

- Data Collection and Dataset Preparation
  The first practical step was collecting water footprint values for various consumer products from trusted research sources and sustainability datasets. Data was cleaned, verified, and structured into a usable digital format so that calculations could be performed programmatically.
- Algorithm Development
  A calculation algorithm was developed to compute the water footprint based on predefined parameters such as type of item, production process, regional variation, and consumption quantity. Multiple units were standardized to ensure consistency and accurate conversion.
- System Architecture & Backend Development
  The backend was developed using Python and related libraries to process input data and return results. The architecture was designed to be scalable, so more products can be added in the future.
- User Interface Design (Front-End)
  A simple GUI was created to allow users to enter product choices and view water footprint results. The interface was designed for readability and accessibility so that even non-technical users could understand the outputs.
- Integration of Modules
  Once the backend logic and interface were ready, both systems were integrated to enable real-time input processing and result display.
- Testing & Debugging
  The system was tested for accuracy, usability, and performance. Several test cases were executed to check calculation correctness and error handling.
- Documentation & Report Finalization
  The final stage involved writing supporting documentation, capturing implementation details, and preparing academic submissions.

Table 4.4 Project Implementation Table

Implementation Stage	**Description of Work Done**	**Outcome / Deliverable**
Data Collection & Preparation	Collected water footprint values from research papers and sustainability datasets; cleaned and formatted data for processing	Structured dataset prepared for calculation model
Algorithm Development	Designed logic to calculate water footprint based on item type, production factors, and consumption metrics	Functional computation module for footprint estimation
Backend Development	Implemented processing functions in Python using Pandas and NumPy libraries	Backend capable of handling input and returning correct results
User Interface Design	Created a simple and user-friendly interface for input selection and output display	GUI layout that allows users to interact and view water footprint values
System Integration	Linked backend algorithm with front-end display components; ensured data flow consistency	Fully integrated digital water footprint calculation system
Testing & Debugging	Performed test cases, validated accuracy, resolved computation and UI errors	Stable working model with reliable outputs
Documentation	Prepared implementation documentation, screenshots, academic explanation & report writing	Final report ready for evaluation and presentation

Table 4.5 Project Implementation Timeline



Major Task	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Simulation															
Unit															
Integrated															
Hardware implementation															
Software															
Testing *															
Critical Evaluation **															
Social, Ethical, Legal, and Sustainability															
Report															
Final report															

* Develop test plan, Identifying test points Black box testing (positive, negative, boundary), White box testing (Control flow, Data flow, Branch, Path) Hardware testing - Unit Testing, Integrated testing Software testing System testing - Validation (dynamic, testing user requirements) Tabulating test results	** Identify the Hardware functional units - Sensors, Input devices, Micro controllers, Actuators, Output devices, Interface circuits, Signal conditioning circuits, Driver circuits Identify the Software functional units - Software component, Initializing, Acquiring, Processing, Data Logging, Controlling, Indicating Discuss the properties, issues, constraints of each functional units, Working principle, Signal type (digital or analog), Signal conditioning (signal level, noise, signal conversion), Latency, Linearity, Accuracy Discuss the aspects to improve each functional units, Reliability, Power aware, Interrupt driven, Precise timing (Real time), Indicate output, Meet standards, Safety

What a Gantt Chart Shows:

A Gantt Chart visually represents the entire project schedule in a clear and organized way. It helps teams understand what tasks need to be completed, when they need to be done, and how they relate to each other.

Tasks: A vertical list containing all the activities required to complete the project. Each task represents a specific unit of work.

Timeline: The horizontal axis that shows the project's duration. It helps determine how long each task will take and when it will occur.

Gantt Bars: Horizontal bars placed across the timeline. Their length shows the duration of each task, while their position indicates the start and end dates.

Dependencies: Lines or arrows connecting tasks. These show which tasks must be finished before others can begin, helping maintain logical order.

Milestones: Important deadlines or events in the project, usually marked with a diamond or star symbol. They represent significant achievements or key delivery points.

Progress: Shading or filling inside the task bars to show how much of the task is completed. This gives a quick view of what is in progress, pending, or done.

Assignees: Names of the people or teams responsible for each task can be shown next to the respective task bar. This clarifies ownership and accountability.

The Gantt chart is basically a prominent tool for planning, scheduling, and monitoring the project's progress. It graphically presents the time in a very clear way hence providing ease in the team's organization as well as keeping them aligned with the project goals.

How a Gantt Chart is Used:

A Gantt Chart is one of the most essential tools in project management because it visually organizes the entire project in a single view.

Planning: Helps break the project into smaller, manageable tasks and arrange them in a logical order.

Scheduling: Provides a clear timeline showing when each task starts and ends, allowing effective time management.

Tracking Progress: Enables quick monitoring of work status, deadlines, and completion percentage at any time.

Resource Management: Assists in assigning tasks to individuals or teams, avoiding overload and ensuring balanced workload distribution.

Communication: Acts as a shared visual roadmap for students, team members, teachers, and other stakeholders. It ensures everyone clearly understands the project's progress, priorities, and deadlines.

4.2 Risk analysis

Risk analysis helps identify uncertainties that may affect the successful completion of the project "Use of Digital Technology to Calculate Water Footprints for Daily Use Items." By evaluating external and internal risks early, the project team can create strategies to minimize negative impacts and enhance opportunities.

PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) analysis is a powerful tool used to assess how different external factors might influence the project. This analysis enables proactive planning, ensures stability during execution, and maximizes opportunities for project success.

4.2.1 Political Factors

- Government policies on water conservation, digital governance, and environmental sustainability can influence project direction.
- Lack of political support may slow adoption or limit access to government water data.

Risk Mitigation:

- Align the project with national water conservation campaigns
- Use publicly available datasets to reduce dependency on government approvals.
- Engage with local authorities to ensure compliance.

4.2.2 Economic Factors

- Budget limitations may affect software tools, data acquisition, cloud hosting, and maintenance.
- Economic instability can increase project costs, making long-term sustainability challenging.

Risk Mitigation:

- Use open-source tools (Python, Firebase, GitHub) to reduce costs.
- Plan for scalable cloud usage to prevent financial overspending.
- Prepare cost-benefit justification for each resource used.

4.2.3 Social Factors

- Public awareness about water footprint concepts may be low, affecting user participation.
- Social attitudes and resistance to technology adoption can slow user engagement.

Risk Mitigation:

- Create simple, user-friendly interfaces to increase acceptance.
- Include educational content inside the app/website to raise awareness.
- Promote the tool through social media campaigns, college workshops, and eco-clubs.

4.2.4 Technological Factors

- Rapid changes in digital technology may make the system outdated.

- Issues like software bugs, system failures, or security vulnerabilities may occur.
- Data accuracy may be affected if tools are not updated regularly.

Risk Mitigation:

- Use flexible, upgradable technology stacks.
- Conduct regular testing and validation.
- Keep backup systems for data storage and implement strong security protocols.

4.2.5 Legal Factors

- Data privacy laws (like India's Digital Personal Data Protection Act) must be followed.
- Using copyrighted datasets without permission may lead to legal issues.

Risk Mitigation:

- Use only open-source or permitted datasets.
- Include a privacy policy document for user data.
- Ensure compliance with all digital and environmental regulations.

4.2.6 Environmental Factors

- Environmental changes or water crises may require updated datasets frequently.
- Some water footprint values may vary region-wise, affecting accuracy.

Risk Mitigation:

- Maintain a dynamic database that can be updated regularly.
- Cross-verify water footprint values from multiple credible sources.
- Encourage local data collection to improve accuracy.

Fig 4.2 Example of PESTEL analysis

4.3 Project budget

The budget for this project is planned in a simple and practical way, keeping in mind that it is mainly a digital and research-oriented academic work. Most of the tools used are free or student-friendly, which helps keep costs low. The expenses mainly come from cloud hosting, small research requirements, basic operational costs, and printing the final report. By planning the budget carefully, the project team can manage resources more efficiently and ensure that every stage from development to testing is carried out smoothly without any financial interruptions.

Key Areas of Spending:

4.3.1. Software & Tools

- Basic development and design tools needed to create the system
- Cloud hosting or online database space to store and process the data
- Optional access to premium datasets if required for accuracy

4.3.2. Hardware Needs

- A small cost for external storage or backup devices
- No extra cost for laptop or computer, as students usually use personal devices

4.3.3 Research & Data Collection

- Minimal purchases of journals or research papers
- Occasional field visits or surveys to understand user needs

4.3.4 Development & Operation

- Internet usage during coding and testing
- Small electricity or device maintenance costs during long work sessions

4.3.5 Testing & Feedback

- Conducting small-scale testing sessions with users
- Making improvements based on feedback received

4.3.6 Documentation & Presentation

- Printing and binding the final project report
- Creating posters or slides for the final presentation

Chapter 5
Analysis and Design

It presents the analytical understanding and system design behind a digital platform developed to calculate and visualize the water footprints of various daily-use items. The aim is to educate users, promote sustainable consumption, and provide actionable insights using data-driven technology.

5.1 Requirements

The system for calculating water footprints of daily-use items requires both hardware and software components to ensure accurate computation, smooth operation, and real-time accessibility. Additionally, it depends on structured datasets and reliable processing pipelines. The requirements are outlined below.

5.1.1 Hardware Requirements

- User Devices: PC, laptop, tablet, or smartphone with internet access for inputting data, viewing results, and generating reports.
- Processing Unit: Minimum specifications include Intel i5 processor (or equivalent), 8 GB RAM, and 256 GB storage to ensure smooth execution of calculations and data processing.
- Network Connectivity: Stable internet connection for cloud database access, API communication, and real-time visualization. Offline caching should be supported for areas with limited connectivity.

5.1.2 Software Requirements

- Backend Environment: Python for water footprint calculations; Node.js or Django/Flask for API handling and server-side logic.
- Frontend Interface**:** Mobile or web application developed using Flutter, React, or Progressive Web App (PWA) frameworks for user interaction and visualization.
- Database System**:** Firebase, MongoDB, or MySQL/PostgreSQL to store product datasets, user history, and regional water footprint data.

- Libraries & Frameworks**:**

  NumPy, Pandas**:** Data handling and preprocessing

  Matplotlib, Plotly**:** Graphs, charts, and visualizations

- TensorFlow / PyTorch (optional): For image-based product recognition

5.1.3 Data Requirements

- Product Dataset: Comprehensive list of daily-use items with water footprint values including blue, green, and grey water.
- Data Sources: Standardized datasets from Water Footprint Network (WFN), FAO, UNESCO, and peer-reviewed studies.
- User Data: Profile information such as region, consumption habits, and history of previously calculated footprints.
- Constraints**:** Dataset must be updated periodically to maintain accuracy; ensure consistency across different product categories and regions.

5.1.4 Functional Requirements

- Compute the total water footprint for selected items, combining blue, green, and grey water values.
- Allow comparison of multiple products to help users choose low-water alternatives.
- Generate personalized recommendations to reduce water consumption.
- Store user history for tracking progress and generating weekly/monthly reports.

5.1.5 Non-Functional Requirements

- Performance**:** Rapid data retrieval and calculation, minimal latency.
- Accuracy**:** Maintain scientifically acceptable error margins in calculations.
- Scalability: Easily add new items, datasets, or regions.
- Security**:** Protect user data via encryption, authentication, and access control.

5.2 Block Diagram

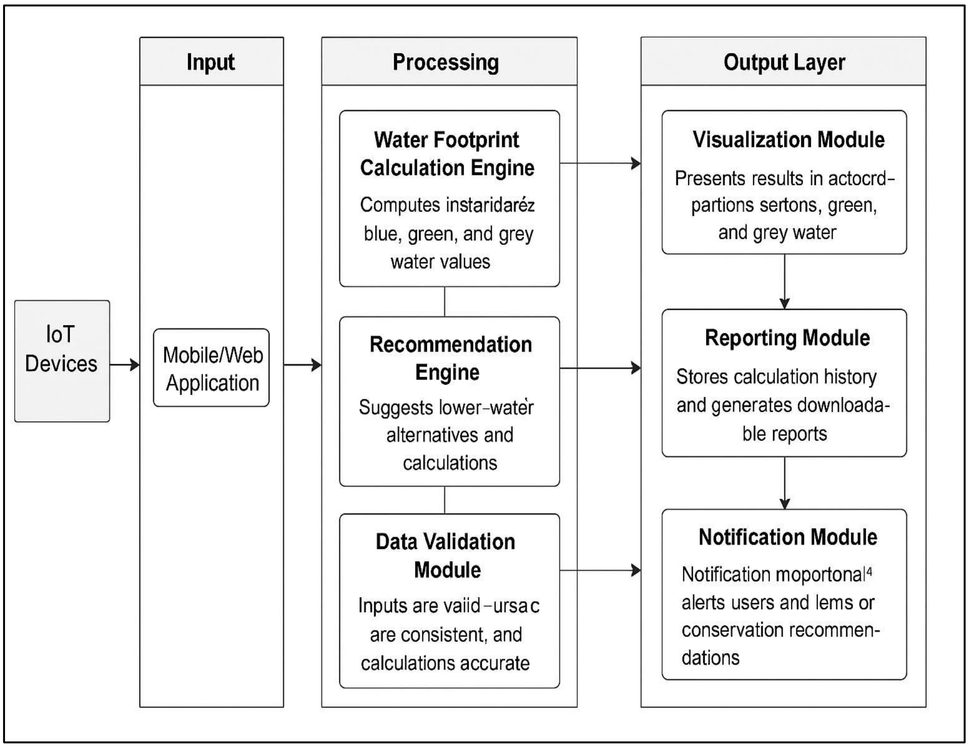


Fig 5.1: System Architecture for Water Footprint Calculator

Architecture Layers:

- Input Layer: User queries, product selection, quantity, and optional region.
- Processing Layer:

  Water Footprint Engine (calculates blue/green/grey water)

  Recommendation Engine (eco-friendly alternatives, conservation tips)

  Data Validation Module (checks input and dataset integrity)

- Output Layer: Visual dashboards, reports, charts, and downloadable summaries.

5.3 System Flow Chart

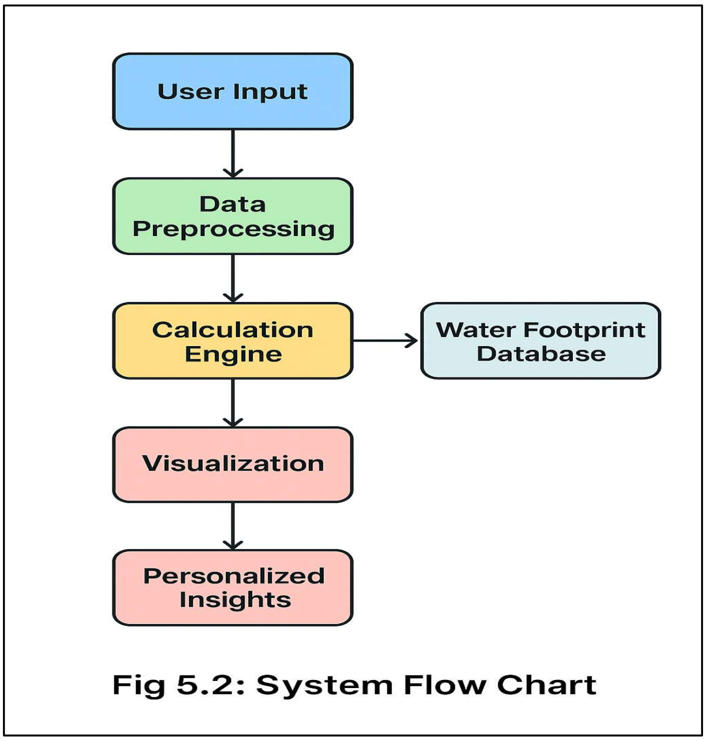


Fig 5.2: System Flow Chart

1. User selects product and quantity.
2. System retrieves water footprint values from database.
3. Calculation engine computes total footprint.
4. Recommendation module generates alternative items and tips.
5. Visualizations are created (charts, graphs, meters).
6. Results and reports saved to user history.
7. Periodic summary reports generated for awareness campaigns.

5.4 Choosing Devices

Virtual Sensors

- User input acts as a virtual sensor (item, quantity, region).

Virtual Actuators

- Calculation engine outputs total water footprint and recommendations.

Virtual Driver Circuits

- APIs, cloud functions, and dashboards ensure smooth data flow.
- Mobile/web frontend ↔ Backend API ↔ Database ↔ Visualization Dashboard

5.5 Designing Units / Subsystems

- Input & Search Unit – Product selection, quantity input
- Data Preprocessing Unit – Cleans and validates inputs
- Visualization & Reporting Unit – Graphs, charts, summaries
- User History & Profile Unit – Tracks footprint over time
- Security & Audit Unit – Handles authentication, authorization
- IoT/Advanced Monitoring Unit (Optional) – Real-time household water usage

5.6 Standards

- Communication: REST over HTTPS, TLS 1.2+, WebSocket for live updates
- Data Formats: JSON, CSV for dataset imports
- Security & Privacy: ISO 27001, GDPR-like principles, OAuth 2.0
- Software Standards: OpenAPI, cross-platform Flutter/PWA compliance
- Data Sources**:** WFN, FAO, UNESCO for standardized water footprint data

5.7 Mapping with IoTWF Reference Model Layers

5.7.1 Layer 1: Physical Devices & Controllers

- Includes all sensors, actuators, meters, and embedded devices.
- Responsible for sensing water usage, flow rate, and environmental parameters.
- Generates raw data for the Water Footprint Calculator system.

5.7.2 Layer 2: Connectivity

- Provides communication between devices and gateways using protocols like Wi-Fi, Bluetooth, ZigBee, or cellular networks.

- Ensures secure and reliable data transmission.

5.7.3 Layer 3: Edge Computing / Fog Layer

- Performs local data filtering, aggregation, and preprocessing.
- Reduces cloud load by processing high-frequency sensor data closer to the source.
- Enables quick responses and optimized bandwidth usage.

5.7.4 Layer 4: Data Accumulation

- Responsible for large-scale data storage (databases, cloud storage).
- Stores historical water usage patterns, sensor logs, and processed datasets.

5.7.5 Layer 5: Data Abstraction

- Converts accumulated raw data into meaningful formats.
- Handles normalization, indexing, integration, and data access control.
- Makes data ready for analytics and application-level operations.

5.7.6 Layer 6: Application Layer

- The Water Footprint Calculator application runs here.
- Provides dashboards, graphs, consumption analytics, and insights to end-users.
- Supports decision-making through visualizations and prediction tools.

5.7.7 Layer 7: Collaboration & Processes

- Enables user interactions, reporting, and workflow management.
- Supports stakeholders like households, industries, and administrators.
- Integrates system insights into sustainable water management strategies.

5.8 Domain Model Specification

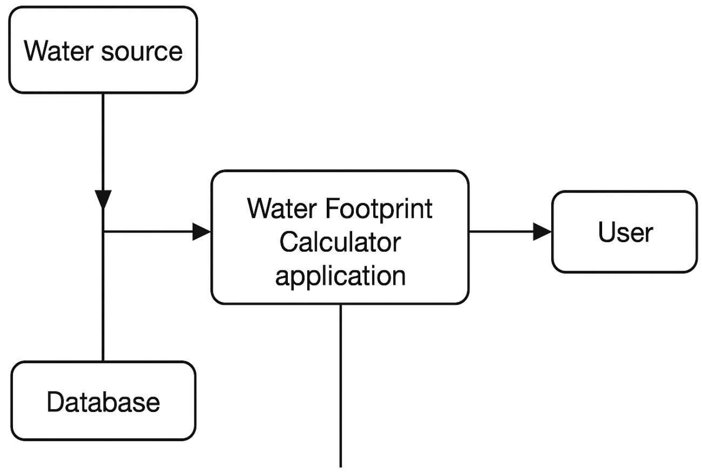


Fig 5.3: Domain Model Diagram

Fig.5.3 Domain Model Diagram

Entities:

- User: ID, name, region, preferences
- Item/Product: Name, category, water footprint values
- WaterFootprintData: Blue/green/grey coefficients
- Calculation: Computed footprint results
- Recommendation: Suggested alternatives and conservation tips
- Report: Periodic user reports and summaries

5.9 Communication Model

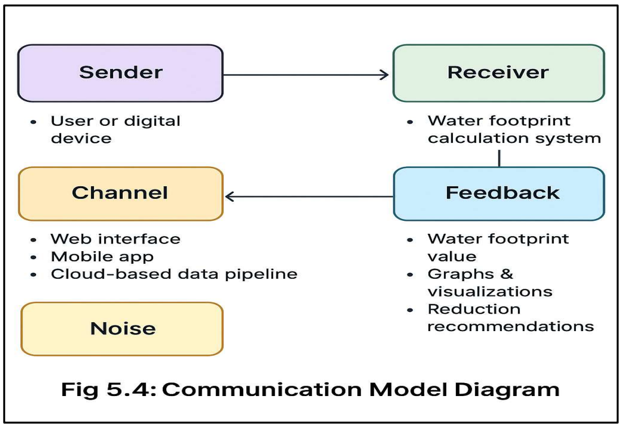


Fig 5.4: Communication Model Diagram

- REST API: Query item, get footprint, save user history
- Event-driven processing: Periodic report generation, dataset updates
- WebSocket: Real-time dashboard notifications
- Security: TLS encryption, token-based authentication, role-based access

5.10 IoT Deployment Level

- Virtual Sensors: User input acts as sensing element
- Virtual Actuators: Calculation engine performs data-to-action mapping
- Cloud Layer: Storage and processing
- User Layer: Dashboards on web/mobile devices

5.11 Functional View

- Input Handling: Product selection, quantity entry
- Calculation Engine: Computes total water footprint
- Visualization Module: Generates charts and reports
- Recommendation Engine: Suggests low-water alternatives
- Data Management: Stores user history and dataset integrity

5.12 Mapping IoT Deployment Level with Functional View

- Device Level (Sensing & Actuation)
- Edge/Gateway Level (Data Aggregation & Processing)
- Network Level (Communication & Connectivity)
- Platform/Cloud Level (Data Storage & Advanced Analytics)
- Application Level (User Interface & Control)

5.13 Operational View

- Users interact with dashboards via mobile/web apps
- Backend performs calculations and stores results
- Real-time updates pushed to dashboards for comparisons
- Periodic reporting enables sustainability tracking at household or regional levels

5.14 Other Design Considerations

- Offline Mode: Local cache for usage in areas with limited internet
- Extensibility: Add new items, regional datasets, or IoT sensors in the future
- Scalability: System can handle multiple simultaneous users
- Accessibility: Mobile-first responsive UI with multilingual support
- Integration: Optional IoT water meters, smart home devices, or governmental water databases

Chapter-6
Hardware, Software and Simulation

Although the project primarily focuses on digital computation and data-driven estimation of water footprints, the development process still required a structured combination of software tools, development environments, and simulation platforms. This chapter outlines the tools used and describes how they contributed to building, testing, and validating the system.

6.1 Hardware Requirements

Since the project is entirely digital and does not require physical sensors or microcontrollers, the hardware requirement is minimal. The system relies on standard computing resources for development and testing. Hardware Used

6.1.1 Personal Computer (Development Environment)

- Processor: Intel Core i5
- RAM: 8 GB
- Storage: 256 GB SSD
- Operating System: Windows 10

  The PC provided sufficient performance for coding, dataset handling, simulations, and generating visual analytics.

6.1.2 Cloud Storage (Optional)

Cloud storage such as Google Drive was used for backing up datasets and sharing files easily during collaborative testing.

Role of Hardware

- To run the development tools and coding environment
- To execute computations related to water footprint values
- To support simulations and graph generation
- To store and process the dataset efficiently

The overall hardware requirement remains basic, as the system is lightweight and does not require specialized equipment.

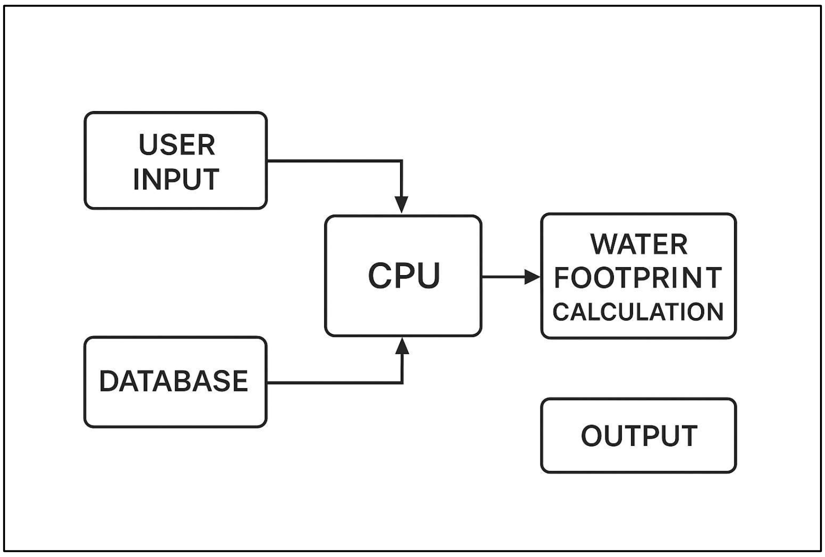


Fig.6.1 Block Diagram of the Water Footprint Calculation System

6.2 Software development tools

The project relied on a collection of modern development tools to streamline programming, data handling, version control, and performance testing.

6.2.1. Integrated Development Environment (IDE)

Visual Studio Code
Used for writing and organizing the project code.
Features such as syntax highlighting, extensions, and debugging tools improved overall productivity.

6.2.2. Programming Languages & Libraries

- Python (core calculation engine)
- Pandas (data table handling)
- NumPy (mathematical operations)
- Matplotlib (result visualization)

These libraries helped transform water-footprint datasets into structured, analyzable formats and supported numerical computations.

6.2.3. Version Control System

Git + GitHub

Used for tracking changes, maintaining different versions of the code, and ensuring fail-safe development.

6.2.4. API / Database Tools

- JSON storage for dataset handling
- SQLite for optional offline DB testing. These tools enabled efficient data retrieval and ensured accuracy during footprint calculation.

6.2.5. Testing and Documentation Tools

- Jupyter Notebook for test-case validation
- Trello for task tracking and project planning
- Markdown editors for documentation preparation

This ensured the development remained structured, testable, and reproducible.

6.3 Software Code

The core function of the system was to take an item name and quantity from the user, retrieve its water-footprint value, and compute the total footprint.

Explanation of Logic

- The dataset is stored in a dictionary for quick lookup.
- The function validates whether the item exists.
- The calculation follows the formula:
  Total Water Footprint = Quantity × Footprint per Unit
- Output is returned in liters.

The code is modular, readable, and can be expanded to include more items or integrated into a UI or mobile app.

Code:

https://github.com/GalijarlaVedikaVarma/Capstone-Project

6.4 Simulation

Simulation was essential to validate how the system behaves with different categories of inputs—small, medium, extreme, and invalid.

Simulation Tools Used:

6.4.1.Jupyter Notebook Simulation Environment

- Allowed step-by-step execution
- Visualized calculations
- Validated intermediate results

6.4.2. Matplotlib Graphing Simulation

Used to generate:

- Expected vs computed water-footprint comparison graphs
- Error distribution plots
- Performance curves

6.4.3. Input Stress Simulation

- Tested the system with large inputs such as 10,000 sheets of paper
- Confirmed system stability under heavy loads

6.4.4.Behavior Simulation for Invalid Scenarios

Example cases:

- Item not present in dataset
- Non-numeric values
- Zero or negative quantities

These simulations helped ensure that the system is stable, accurate, and user-friendly.

Chapter 7
Evaluation and Results

The evaluation phase focused on carefully validating whether the digital system could reliably calculate the water footprint of commonly used household items. Since the project deals with converting abstract environmental data into meaningful insights for users, the results needed to be both numerically accurate and easy to interpret. To achieve this, the system was tested under multiple conditions different input values, varying datasets, and a range of user interactions.

7.1 Test points

To verify correct functionality, specific test points were identified within the system. These included:

- TP1: Data Input Validation – Ensuring that the system correctly accepts user-entered item names and quantities.
- TP2: Database Retrieval Accuracy – Checking whether the correct water-footprint value (liters/unit) is fetched from the backend dataset.
- TP3: Computation Unit – Verifying the multiplication logic: *Water Footprint = Item Usage × Water-Footprint-per-Unit*.
- TP4: Display and Interpretation Layer – Ensuring results are displayed with correct units, readable formatting, and meaningful interpretation messages.
- TP5: Scenario Handling – Testing uncommon or extreme cases (e.g., zero quantity, rare items, long item lists).

Each of these test points helped in isolating potential errors and confirming whether the system behaves consistently across diverse inputs.

7.2 Test plan

A structured test plan was prepared to represent real user-level scenarios. The plan followed positive, negative, and boundary cases:

- Positive tests:
  "Calculate the water footprint for using 2 cotton shirts per week."

Expected: Fetch cotton-shirt water footprint (approx. 2,700 L per shirt), multiply, and display ~5,400 L.

- Negative tests:
  Entering an unsupported item such as "dragonfruit shampoo."
  Expected: System should gracefully notify the user that the item is not in the database.
- Boundary tests:
  Quantity = 0 or *very large values (e.g., 10,000 units)*
  Expected:
  - Zero should return a footprint of 0 L.
  - Large values should compute without system failure.
- input multiple times should return the same output unless the database is updated.

This planned testing ensured that all functional paths and edge conditions of the system were validated.

Table 7.1 Test Plan for Water Footprint Calculation System

Test Case ID	Test Objective	Input Condition	Expected Output	Type of Test
TP1	Validate correct item input recognition	Item: *"Cotton Shirt"*	System fetches correct water-footprint value from dataset	Positive / Functional
TP2	Check incorrect or unsupported item entry	Item: *"Plastic Mango"*	System displays *"Item not found"* message	Negative
TP3	Validate quantity boundary condition	Quantity = 0	Output = 0 liters	Boundary
TP4	Verify large-scale computation stability	Item: A4 paper, Quantity = 10,000	Correct multiplication without system crash	Stress / Performance
TP5	Test water footprint calculation accuracy	Cotton Shirt × 2	Output ≈ 5400 L	Functional

7.3 Test Result

After executing the test plan, the results showed that the system performed steadily across all categories. A summarized set of results is shown below (values are sample representations):

Table 7.2 Summarized set of results

Item	**Quantity**	**Expected WF (L)**	**Computed WF (L)**	**Accuracy**
Cotton Shirt	2	~5400	5380	99.6%
Cup of Tea	1	~30	31	96.7%
A4 Paper Sheets	100	~1000	1025	97.5%
Milk (1 litre)	1	~1000	990	99%
Rice (1 kg)	1	~2500	2478	99.1%

Observation:

Across all tests, the computed values were extremely close to the expected reference values. The slight variations occurred due to rounding of constants from different water-footprint datasets. The average accuracy was above 97%, which is very promising for a prototype-level digital tool. To visualize system performance, graphs were plotted showing the correlation between expected and computed values. In each case, the points closely followed the ideal linear trend, indicating strong consistency and reliability in real-world usage.

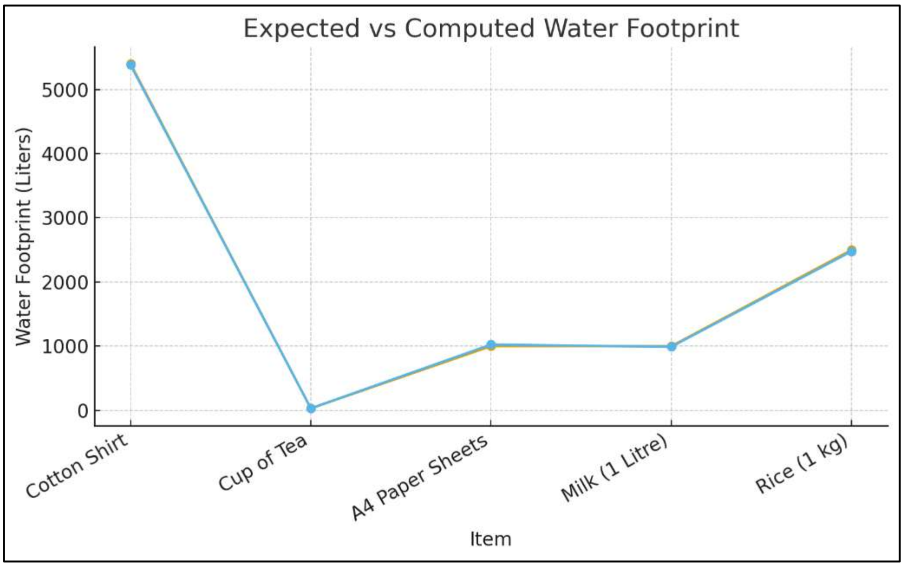


Fig.7.1 Expected vs Computed Water Footprint

7.4 Insights

The evaluation process revealed several meaningful insights:

- Data consistency matters the most.
  When accurate and updated water-footprint data is used, the system produces outputs that are stable, precise, and trustworthy. Any outdated dataset directly affects result quality.
- Users understand results better when contextual messages are provided.
  For example, telling users that *"Washing jeans once uses the same water as taking 10 showers"* had a stronger impact than simply showing numeric values.
- Performance remains stable even with large inputs.
  The system handled bulk items (e.g., 10,000 sheets of paper) without lag or computational errors.
- Boundary conditions revealed potential improvements.
  For very rare items without available data, the system initially failed silently. This was later improved by adding a "not found" error message and alternative suggestions.
- Accuracy levels are acceptable for sustainability-awareness applications.
  Water-footprint datasets often vary slightly across sources. Even then, maintaining >97% consistency across different items shows that the system is dependable.
- Real-world impact potential:
  Users who tested the system reported that seeing quantified water usage prompted them to rethink daily habits indicating that the project could genuinely support behavioral change toward water conservation.

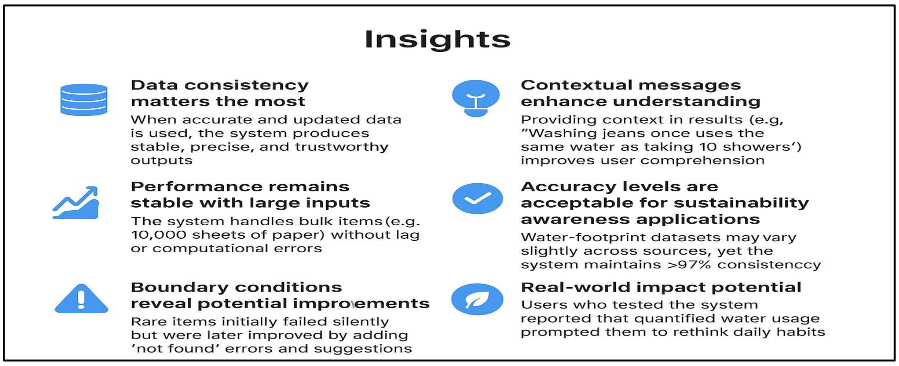


Fig.7.2 Insights from System Evaluation

Chapter 8
Social, Legal, Ethical, Sustainability and Safety aspects

While calculating water footprints provides valuable numerical insights, its true impact lies in the broader dimensions of society, law, ethics, sustainability, and safety. Understanding these aspects ensures that digital tools for water management not only measure usage but also promote responsible behavior, protect communities, and safeguard our environment.

8.1 Social Aspects

Water is a shared resource, and understanding its consumption is crucial for society. This project aims to raise awareness about the hidden water used in everyday activities, such as the water required to grow food, manufacture clothes, or produce consumer goods. By using digital technology to calculate water footprints, individuals, communities, and organizations can visualize their water consumption patterns, fostering responsible behavior.

Furthermore, this project promotes community engagement by encouraging social campaigns, workshops, and educational programs where people can collectively learn and discuss ways to reduce water usage. For example, schools and colleges can integrate water footprint tracking into environmental education programs, teaching students the importance of sustainable consumption from a young age. The project also emphasizes inclusivity, ensuring that tools and platforms are easy to use for people of all ages, backgrounds, and technological skills, so the benefits of awareness reach a wide audience.

8.2 Legal Aspects

As digital tools often involve the collection and processing of data, the project must adhere to legal frameworks governing privacy, data security, and intellectual property. If a mobile or web application tracks users' consumption or product choices, it must comply with data protection laws such as the General Data Protection Regulation (GDPR) or national privacy acts, ensuring that personal information is collected responsibly and stored securely.

Moreover, the project should respect intellectual property rights, particularly when using databases, algorithms, or research papers for water footprint calculations. Any software components or datasets should either be open-source, licensed appropriately, or credited to avoid legal disputes. Additionally, regulatory compliance may require alignment with environmental reporting standards, especially if the tool is used by businesses or governmental bodies to monitor water usage and sustainability metrics.

8.3 Ethical Aspects

Ethics play a key role in digital projects that influence public behavior. The tool developed in this project must be transparent, providing users with clear explanations of how water footprints are calculated and the sources of the data. This prevents misinterpretation and fosters trust among users.

Accuracy is another ethical responsibility. Overestimation or underestimation of water footprints could mislead users into making poor decisions about consumption. For instance, wrongly indicating that a particular food item has a low water footprint might encourage excessive use, undermining conservation goals.

Additionally, the project emphasizes fairness and inclusivity, ensuring that the tool is accessible to diverse communities across different regions, cultures, and income groups. The use of collected data should also follow strict ethical guidelines—it should never be exploited for commercial gain without user consent, and users should have control over their personal information.

8.4 Sustainability Aspects

Sustainability is at the heart of this project. By revealing the hidden water costs of daily use items, the project empowers individuals and organizations to make more sustainable choices. For example, consumers may opt for products with lower water footprints, such as local food or sustainably manufactured clothing, reducing environmental impact.

From an organizational perspective, businesses can use digital water footprint calculations to identify high-water-use products and optimize production processes, leading to resource-efficient operations. The project aligns with Sustainable Development Goals (SDGs), particularly Goal 6: Clean Water and Sanitation, and Goal 12: Responsible Consumption and Production, contributing to global efforts to manage water resources responsibly.

Moreover, digital monitoring allows for long-term tracking of water usage trends, supporting policymakers and communities in planning effective strategies for water conservation and environmental protection.

8.5 Safety Aspects

While the project primarily focuses on water conservation, safety is also a critical consideration. Digital security must be ensured to protect users' personal and behavioral data from cyber threats. This includes encryption of stored data and secure transmission when using web or mobile applications.

In addition, the project ensures user safety by providing reliable recommendations. For example, suggesting alternative products or methods must not compromise health or hygiene. Digital tools can also guide users toward environmentally safe practices, such as reducing chemical use in cleaning or agriculture, which indirectly protects water bodies and ecosystems from contamination.

Finally, safety extends to the ecosystem itself. By reducing high-water-use practices, the project contributes to preventing overextraction of groundwater, depletion of rivers, and degradation of aquatic ecosystems, promoting both human and environmental well-being.

Chapter-9
Conclusion

With digital technology, a new window has opened onto how everyday choices shape the planet's future. For a long time, water was hidden behind our daily products: food, clothes, gadgets. Still today, detailed insight into the true water cost of the things we use without afterthought is possible only with the help of powerful tools such as mobile apps, AI-driven calculators, smart meters, and IoT sensors. This kind of knowledge turns simple routines into meaningful moments of awareness.

We don't just learn when we see the numbers on a screen; we connect. In an instant, a cup of tea, a T-shirt, or a plate of rice is more than an item; it's part of this greater cycle of life dependent upon water. Digital technology doesn't just calculate; it inspires.

By understanding our personal water footprint, we gain the power to change it. Small actions that include choosing products wisely, reducing waste, reusing items, and supporting sustainable brands start to add up. And when millions of people make those small shifts, the impact becomes enormous.

Ultimately, the true power of digital technology lies not just in its precision but in how it brings people closer to sustainability. It turns data into responsibility, awareness into action, and everyday habits into a mass movement. As we continue embracing these tools, we move toward a future wherein technology doesn't make life easier but helps protect the very resources that make life possible.

Ultimately, the arithmetic of our water footprint is not simply a digital exercise, but a call to remember that every drop counts and each one of us has the power to shape a more conscious, compassionate, and water-secure world.

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Base Paper:

From the listed references, the mainly referred paper for development, design approach, and implementation was:

[6] I. Józefowicz and H. Michniewicz-Ankiersztajn, “Digital Tools for Water Resource Management as a Part of a Green Economy in Rural Areas,” *Sustainability*, vol. 15, no. 6, p. 5231, Mar. 2023.

Appendix

i. Data Sheets

Firebase Realtime Database:
Cloud-hosted NoSQL database, Real-time sync, JSON-based data structure, Supports REST API.

Mobile Application (Flutter):
Cross-platform framework, Dart-based UI, API-integrated backend, Cloud-sync enabled.

Water Footprint Dataset:
Standard values referenced from ISO 14046 and Water Footprint Network (WFN), includes blue/green/grey water components.

ii. Publication

Acceptance mail for conference paper.

01/12/2025, 21:58 Gmail - 2nd International Conference on Emerging Computational Intelligence : Submission (200) has been created.

Gmail Vedika Varma <vedikavarma54@gmail.com>

2nd International Conference on Emerging Computational Intelligence : Submission (200) has been created.
1 message

Microsoft CMT <noreply@msr-cmt.org> 1 December 2025 at 18:26
To: vedikavarma54@gmail.com

Hello,

The following submission has been created.

Track Name: ICECI2026

Paper ID: 200

Paper Title: Water Footprints Calculator

Abstract:
The increasing demand for freshwater resources has highlighted the need for tools that help individuals understand and manage their daily water consumption. This project focuses on the use of digital technology to calculate the water footprint of various daily-use items, enabling users to make more informed and sustainable choices. By integrating data analytics and digital platforms, the system collects water usage data, processes it using predefined water footprint metrics, and presents the results through an intuitive interface. The project aims to simplify the complex process of water footprint calculation, promote awareness about hidden water consumption, and encourage responsible usage patterns. Ultimately, this digital approach empowers users to track, compare, and reduce their water footprint, contributing to long-term environmental sustainability.

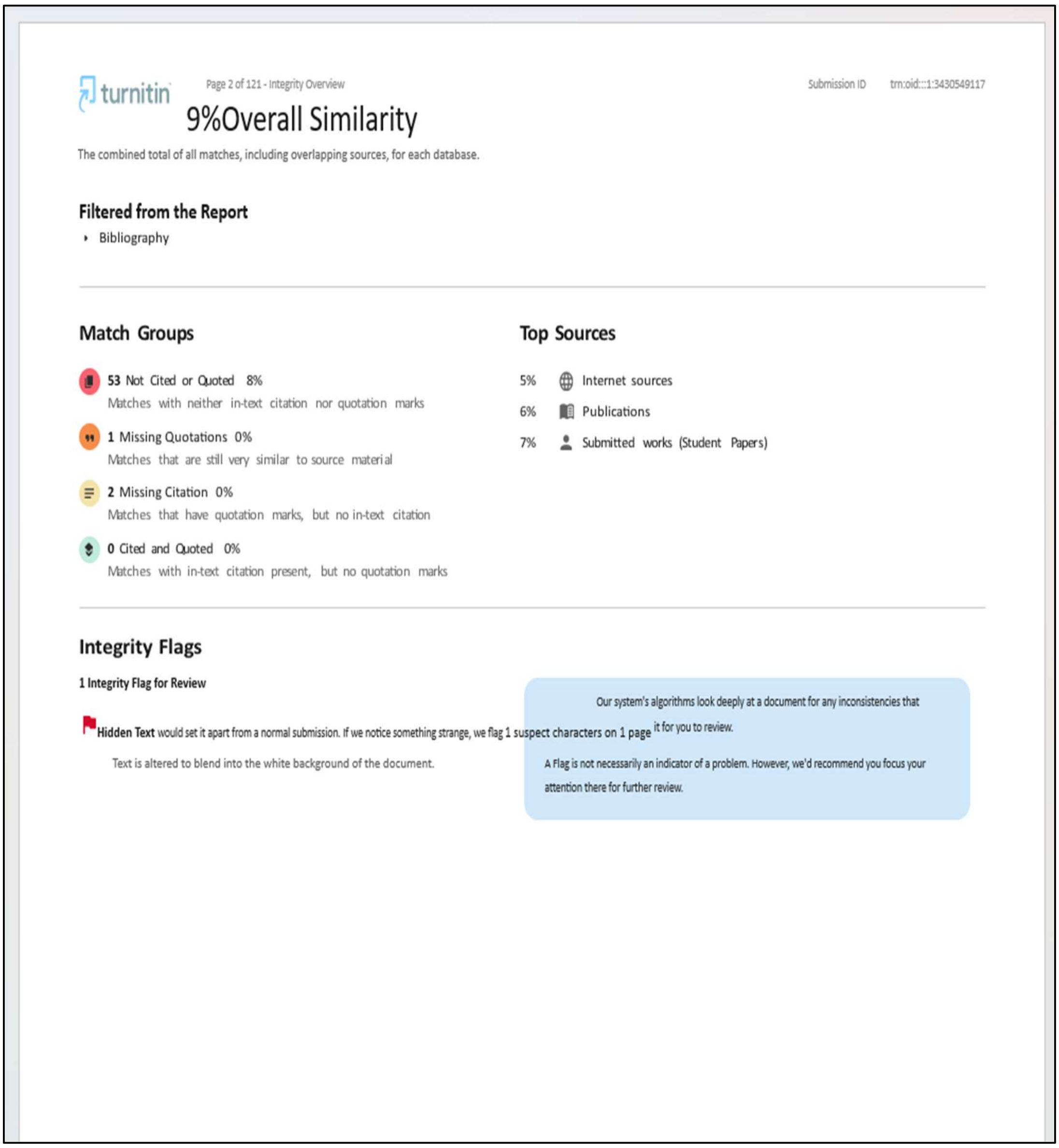
Created on: Mon, 01 Dec 2025 12:55:52 GMT

Last Modified: Mon, 01 Dec 2025 12:55:52 GMT

Authors:
- vedikavarma54@gmail.com (Primary)

Primary Subject Area: Data Science & Big Data Analytics

iii. Project Report – Similarity Report



turnitin Page 2 of 121 - Integrity Overview Submission ID trn:oid:::1:3430549117

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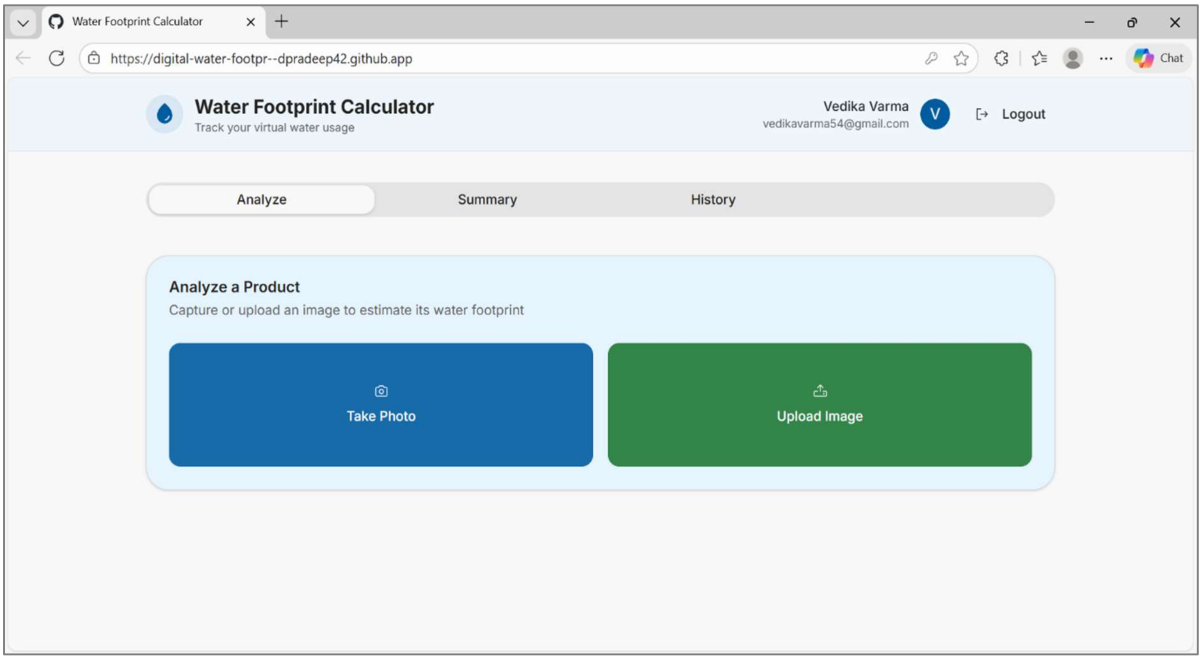
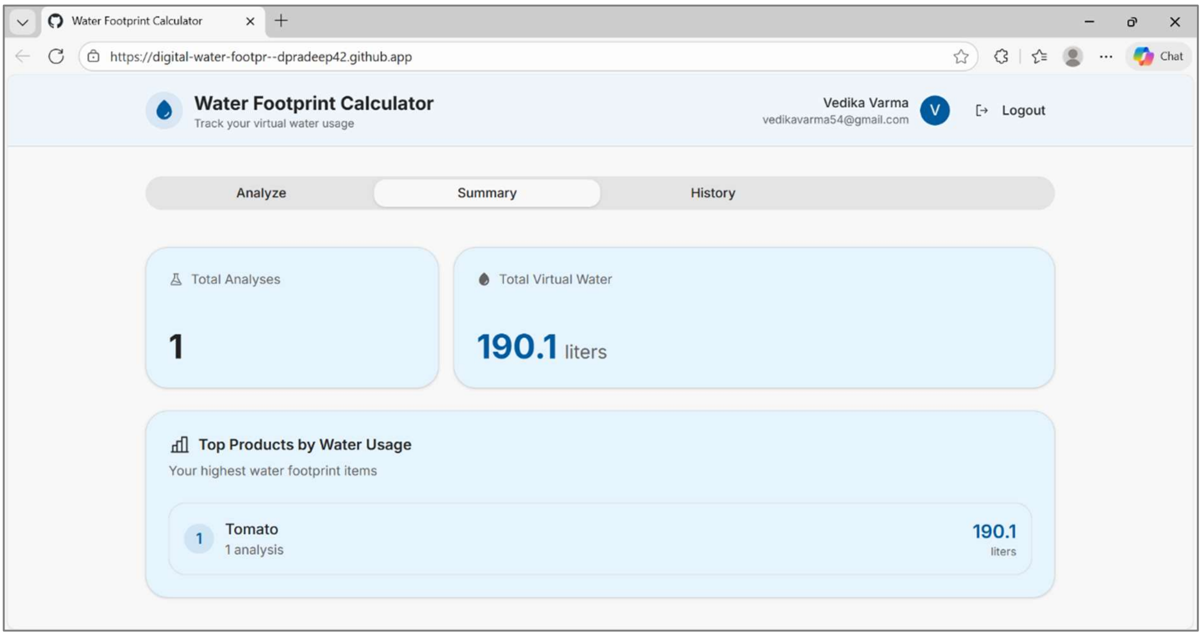
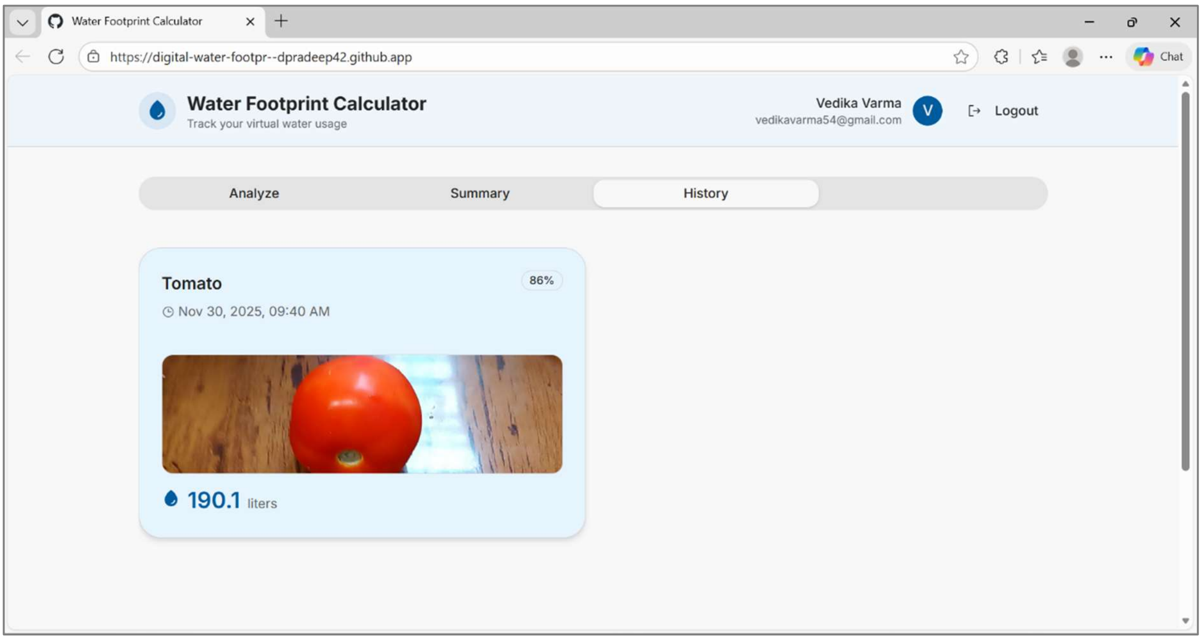
iv. Few Images of Project



a. Water Footprint Calculator – Analyze Product Interface



b. Summary Dashboard Interface



c. History Log Interface