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Development of Pediatric IV Flow Rate Monitor for Humanitarian Settings

# Problem statement and goals

The goal is to develop a compact, precise, energy-efficient and cheap IV flow monitor with an intuitive UI and reliable alerts. It must achieve ±1% accuracy in drop detection. The device will use a drop detection system based on an IR light gate (emitter + receiver) approach, calibrated to support 10, 15, 20, 60, and ideally 100 gtt/mL drip sets. The device should be ≤100 × 50 × 25 mm and ≤100g, reducing bulk compared to existing solutions. It must operate for at least 360 hours. The UI will feature a display, color-coded LEDs, and an alarm system for critical alerts. The system will include audible and visual alarms to ensure effective monitoring in various environments.

# Research Questions

To evaluate the feasibility and effectiveness of the proposed IV flow meter, this research will address the following key questions:

* How accurately does the IV flow meter measure flow rates between 1–100 mL/h under controlled laboratory conditions, and how does its error margin compare to the ±1% drop detection accuracy of the DripAssist (*DripAssist - Shift Labs, Inc. - PDF Catalogs | Technical Documentation*, n.d.)? Additionally, does this accuracy remain stable when extending the range to 200 mL/h for adult use?
* What cost-effective materials and production methods can be used to manufacture an IV flow meter for under $59.22 (=52.28 CHF[[1]](#footnote-0)), a figure to remain comparable to DripOMeter (Venkatesh et al., 2022), per unit while ensuring ±1% accuracy and a battery life of at least 360 hours?
* What UI design principles can improve ease of use for IV flow meters with minimal training, considering language barriers and limited technical expertise?

# Methods

To evaluate the feasibility and effectiveness of the proposed IV flow meter, this research will employ a combination of experimental testing, cost analysis, and usability studies. Each research question will be addressed as outlined below.

The IV flow meter’s accuracy in measuring flow rates between 1–100 mL/h will be tested using standardized IV drip sets (10, 15, 20, 60, and 100 gtt/mL). The device will be calibrated against a high-precision digital flow meter, and its error margin will be compared to the ±1% drop detection accuracy of the DripAssist flow monitor. Additional tests will extend the range to 200 mL/h to determine accuracy for adult use.

To identify cost-effective materials and production methods, a comparative analysis of available electronic components and sensor technologies will be performed. The design will prioritize affordability without compromising performance, aiming to keep production costs as low as possible per unit. Prototyping will involve 3D printing for housing components and readily available electronic parts, with iterative testing to refine material selection. Manufacturing feasibility will be assessed through consultation with industry experts and suppliers to estimate bulk production costs and scalability potential.

The UI will be designed with minimal training requirements in mind, using a display, color-coded LEDs, and an alarm system for critical alerts. Feedback will be gathered from 2-3 medical professionals or field workers with experience in low-resource settings. These individuals will provide insights on ease of use, readability, and alarm responsiveness based on their interaction with the device. Their feedback will inform iterative design improvements to enhance accessibility, particularly in environments with language barriers and limited technical expertise.

These methodologies will ensure that the IV flow meter meets the accuracy, affordability, and usability requirements essential for effective deployment in humanitarian settings.

# Planning

## Gantt chart

The project begins with research and planning in March, gathering information from existing products and humanitarian settings, preparing the design process. From April onwards, the development and experimentation phase follow an agile approach, incorporating brainstorming, system architecture planning, and rapid prototyping to refine multiple (2-3) design iterations before converging on an optimized prototype. Writing and documentation are done throughout the process, to ensure that experimental findings and design insights are recorded right as they happen. This allows flexibility to adapt based on test results and ensures steady progress toward the final submission in August.

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KI-generierte Inhalte können fehlerhaft sein.

*Figure 1: Project Timeline Gantt Chart*

The timeline will be updated periodically to account for unforeseen delays, scope changes, feedback from supervisors requiring revisions or additional approvals, technical challenges, and experience gained from previous phases that suggest better approaches.

## Mind Map

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*Figure 2. Project Mindmap*

The mind map provides a structured overview of the key aspects of the project, ensuring focus on the most critical elements, including the Minimum Viable Product (MVP). It highlights both technical aspects and humanitarian challenges, helping to maintain a clear direction throughout development.

# Data Management Plan (DMP)

This DMP outlines data collection, generation, and reuse strategies. It is expected to evolve throughout the project.

## Data collection

| **dataset** | **data type** | **data format** | **data documentation** |
| --- | --- | --- | --- |
| *IV flow rate measurement* | *Sensor data* | *CSV export from microcontroller* | *Variables include timestamp, drip rate (gtt/min), flow rate (mL/h), total volume administered (mL), battery level (%).*  *Dataset size: ~500 observations. Data files and calibration scripts are stored and version-controlled via the GHE GitHub repository.* |
| *Power consumption during operation* | *Electrical measurement data* | *CSV export from microcontroller* | *Includes timestamp, voltage (V), current (mA), and power (mW). Logged at ~1 Hz during typical cycles for each sensor prototype. Data and corresponding Arduino measurement code are maintained in the GHE GitHub repository.* |
| *Structured feedback from supervisor and medical professionals* | *Observational data* | *Notes → Google Sheets → CSV* | *Structured feedback documented after sessions, focusing on UI usability, accuracy perception, and practical improvements. Feedback from supervisor and up to 3 medical professionals, estimated total ~5 entries.* |
| *Source Code* | *Firmware, logging, and analysis scripts* | *Arduino (C++), Python, R* | |  | | --- |   *All firmware, logging tools, and analysis scripts are stored under version control in the GHE GitHub repository. Folder structure follows GHE guidelines, with detailed documentation in Readme.md files and inline comments for reproducibility.* |

## Data storage

Raw datasets collected from microcontroller-based systems and observational calibrations will be directly exported or digitized into CSV files and stored in the provided Google Drive folder under data/raw\_data. Structured observational feedback will be digitized and stored separately in CSV format within data/raw\_data. Secondary data (PDF standards documents) will be stored in data/raw\_data if applicable, or clearly referenced in documentation if publicly accessible.

Data analysis will be performed using primarily Excel. The raw datasets will remain unaltered to ensure data integrity. Processed data and analyses will be systematically version-controlled and stored within the provided Google Drive folder, following the recommended directory structure from Global Health Engineering.

All data collection scripts, firmware code, and data analysis tools are maintained in a dedicated GitHub repository under the Global Health Engineering organization. The repository follows the recommended folder structure (src/, firmware/, data/, analysis/, docs/) to ensure traceability and reproducibility. Each version of the code and dataset is committed with meaningful messages and tagged for key milestones. Where applicable, README.md files provide instructions for reproducing results, and changes are documented to maintain a transparent development history.

# Budget

| **Expense** | **Amount** | **Unit Price [CHF]** | **Total Price [CHF]** |
| --- | --- | --- | --- |
| ***Core Electronics & Processing*** |  |  |  |
| [Arduino Pro Mini (3.3V)](https://www.aliexpress.com/item/4001172146130.html) | 3 | 2.13 | 6.39 |
| [FTDI USB-to-Serial Adapter](https://www.aliexpress.com/item/1005006445462581.html) | 2 | 1.23 | 2.46 |
| [3.3V USB Power Supply for Arduino](https://de.aliexpress.com/item/1005008375242304.html) | 1 | 1.48 | 1.48 |
| [DC/DC 1.5V -> 3.3V Converter](https://de.aliexpress.com/item/1005007286702398.html) | 2 | 0.95 | 1.9 |
| ***Sensors & Input Components*** |  |  |  |
| Infrared LED Diodes (940nm) ([Receiver](https://www.aliexpress.com/item/1005004060113525.html) + [Emitter](https://www.aliexpress.com/item/1005004060113525.html)) | 1 | 1.57 | 1.57 |
| [TSOP38238 IR Receiver](https://www.aliexpress.com/item/1005006814318117.html) | 1 | 1.84 | 1.84 |
| [MOSFET (for IR LED switching)](https://www.aliexpress.com/item/1005008257932233.html) | 1 | 1.99 | 1.99 |
| [Current/Power/Voltage Sensor](https://de.aliexpress.com/item/1005006109458834.html) | 1 | 1.23 | 1.23 |
| ***Power & Battery Components*** |  |  |  |
| [AA Batteries](https://www.digitec.ch/de/s1/product/energizer-lithium-cr2032-12-stk-cr2032-240-mah-batterien-akkus-21606514) | 1 | 9.5 | 9.5 |
| [AA Battery Holder](https://www.aliexpress.com/item/1005006225310014.html) | 1 | 1.71 | 1.71 |
| ***Circuitry & Prototyping*** |  |  |  |
| [Resistor Kit](https://www.aliexpress.com/item/1005003276193064.html) | 1 | 10.59 | 10.59 |
| [Capacitor Kit](https://www.aliexpress.com/item/1005005282086375.html) | 1 | 2.94 | 2.94 |
| [Jumper Cables](https://www.aliexpress.com/item/1005002490065496.html) | 1 | 4.97 | 4.97 |
| [Prototyping PCB Boards](https://www.aliexpress.com/item/1005007129892552.html) | 1 | 3.13 | 3.13 |
| [Breadboard MB-102](https://www.aliexpress.com/item/1005004532352681.html) | 1 | 2.79 | 2.79 |
| [LED Kit](https://www.aliexpress.com/item/1005005708510866.html) | 1 | 1.14 | 1.14 |
| Button Kits ([Power](https://www.aliexpress.com/item/32873386670.html) & [Press](https://www.aliexpress.com/item/1005004198996493.html)) | 1 | 2.25 | 2.25 |
| ***Display & Feedback Components*** |  |  |  |
| [Piezo Buzzer (Alarm)](https://www.aliexpress.com/item/4000829554492.html) | 1 | 1.69 | 1.69 |
| [HD44780 16x2 LCD + I2C Module](https://de.aliexpress.com/item/615421183.html) | 1 | 2.43 | 2.43 |
| ***Data Logging & Storage*** |  |  |  |
| [Micro SD Card (32GB)](https://www.aliexpress.com/item/1005008119527497.html) | 1 | 3.39 | 3.39 |
| [Micro SD Card Module (Arduino)](https://www.aliexpress.com/item/32787679017.html) | 1 | 1.44 | 1.44 |
| [Micro SD Card Adapter (USB)](https://www.aliexpress.com/item/1005008119527497.html) | 1 | 1.49 | 1.49 |
| ***Real-Time Clock (RTC) & Timekeeping*** |  |  |  |
| [RTC Module DS3231](https://de.aliexpress.com/item/1005007143596890.html) | 1 | 0.89 | 0.89 |
| ***Manufacturing & Miscellaneous*** |  |  |  |
| [PLA Filament (1kg)](https://www.3djake.ch/en-CH/bambu-lab/pla-matte-ice-blue-1) | 1 | 26.5 | 26.5 |
| Delivery Cost | 1 | 13.59 | 13.59 |
| IV Infusion Set (Donated) | 1 | 0 | 0 |
| ***Buffer*** |  |  |  |
| Contingency Budget (ca. 40%) |  |  | 80 |
| ***Total*** |  |  | ***189.3*** |

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1. Currency conversions in this document use rates as of March 2025. [↑](#footnote-ref-0)