A MICRO- CONTROLLER BASED MODEL FOR A REAL-TIME VEHICLE OVERLOADING PREVENTION

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A Thesis Submitted to the Institute of Postgraduate Studies of Kabarak University in Partial Fulfillment of the Requirements for the Award of Master of Science in Information Technology Degree

KABARAK UNIVERSITY

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DECLARATION

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James Ndungu Njuguna

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The thesis entitled “**"A Microcontroller Based Model for A Real-time Vehicle Overloading Prevention**″ and written by **James Ndungu Njuguna** is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed the thesis and recommend that it be accepted in partial fulfillment of the requirements for the award of Doctor of Philosophy in Information Technology.

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I want to thank God first and foremost for the gift of life and for his provision, without which I could not have progressed this far in my academic career. In fact, God's grace is the reason I have come this far.

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Last but not least, I would like to thank Kabarak University, a Christian-based university. I also acknowledge Laikipia University for the opportunity to further my studies.

DEDICATION

This proposal is dedicated to my wife, Susan Wairimu, for her unwavering support throughout the duration of this study and for the enormous sacrifices she made to ensure my success.

May God's blessings be upon her.

ABSTRACT

Overloading a vehicle can have fatal effects. It occurs when a vehicle's maximum allowable weight limit is exceeded. Overloading is an unlawful offense. According to Section 56 of Kenya's Traffic Act, Cap 403, the tare weight should be used to determine whether a vehicle is actually overloading. However, on Kenyan highways, law enforcement officials tend to focus on the cargo area of the vehicle. For instance, in the case of Public Service Vehicles (PSVs), the number of passengers is utilized to determine if a vehicle is overloaded. If the vehicle has not exceeded the carrying capacity, it is incorrectly assumed to be in compliance. This misconception has led to many vehicles being on the road when overloaded, which has been linked to increased road carnage leading to death, economic loss to the country, and making those people who have been living independent lives become dependents as a result of injuries sustained during the road accidents. All other causes of road accidents, such as speeding, vehicle and road conditions, and human errors, were considered normal in this study. The proposed research study aimed to employ a preventive approach to vehicle overloading using smart microcontroller technology that would prevent the engine from starting when the vehicle's tare weight was exceeded or when the vehicle's seating capacity was exceeded. To achieve this, load cells were used for weight detection, while a Passive infrared sensor (PIR)- based motion detector was used to count the number of passengers entering or exiting the vehicle. Weaknesses in the current methods used to detect and prevent overloading were identified through a desktop research methodology aimed at providing a solution. The researcher endeavored to demonstrate how overloading would be prevented by using a microcontroller-based model. The design of the model, which emanated from the suggested solution, was developed and implemented using Design Science Research to show the feasibility of the model. The prototype was evaluated to see whether the research objectives were achieved using Proof of Concept methodology. Pilot testing showed that the functional requirements were met. An observation method was employed in data collection. The data collected was analyzed using descriptive data analysis methods. Thus, it was concluded that the general concept was workable and realistic, with the recommendation that the Kenyan government should upscale this research report and re-examine current policies to facilitate the faster deployment of the system.

Keywords: *Vehicle, Integrated, Tare weight, Overloading, Microcontroller.*

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ABBREVIATIONS AND ACRONYMS

ALU-	Arithmetic Logic Unit
ATM-	Automatic Teller Machine
ASCII-	American Standard Code for Information Interchange
BS-	Base Station
BSC-	Base Station controller
CPU-	Central Processing Unit
BTS-	Base Transceiver Stations
DC-	Direct Current
DSR-	Design Science Research
ESRAS-	Extremely Serious Road Accidents
GPS-	Global Positioning System
GSM-	Global System for Mobile Communication
IC-	Integrated Circuit
IOT-	Internet of Things
I/O-	Input/output
IR-	Infra-Red
KeNHA-	Kenya National Highway Authority
Kgs-	Kilograms
Kes-	Kenya Shilling
LED-	Light Emitting Diode
LCD-	Liquid Crystal Display
MS-	Mobile Station
MSC-	Mobile Switching Center
NSS-	Network Switching System

NTSA-	National Transport Security Agency
OCR-	Optical Character Recognition
PC-	Program Counter
PEROM-	Programmable Erasable Read Only Memory
POC-	Proof of Concept
PPDIOO-	Prepare Plan, Implement, Optimize
PSTN-	Public Switched Telephone Network
PSV-	Public Service Vehicles
RAM-	Random Access Memory
ROM-	Read Only Memory
RTO-	Recovery Time Objective
SMS-	Short Messaging Services
SP-	Stack Pointer
VWS -	Virtual Weighbridge System.
WHO-	World Health Organization
WIM-	Weigh In Motion

OPERATIONAL DEFINITION OF TERMS

Public Service Vehicle: This refers to the categories of vehicles that transport passengers and luggage.

Matatu: Mode of transport commonly used by Kenyans.

Embedded Systems: It is a combination of computer software and hardware that is either fixed in capability or programmable.

Analogue Signal: A signal that is continuous in nature

Digital Signal: An Analogue Signal that is discrete in nature.

Load Cells: Used to measure weight

Logic Gates: Are used in operations of embedded systems.

Cloud Services: The term "cloud services" refers to a wide range of services delivered on demand to companies and customers over the internet.

GSM: GSM stands for Global System for Mobile Communication. It is a digital cellular technology used for transmitting mobile voice and data services.

Microcontroller: A chip that controls all the operations of the system

CHAPTER ONE

INTRODUCTION

This chapter provides a brief overview of the issues that underpin this study, including the overloading of cars in contravention of the standards established for each vehicle category. The chapter proceeds to describe the study's objectives, research question, scope, assumptions, and anticipated outcomes.

1.1 Background to the Study

According to World Health Organization (WHO) estimates, up to 50 million people suffer non-fatal injuries as a result of traffic accidents each year, and over 1.35 million people die on the world's roadways. Road traffic accidents are currently predicted to overtake high-profile diseases like malaria and HIV-AIDS to become the fifth major cause of death worldwide by 2030, ranking as the eighth top cause of death internationally. They have a significant socio-economic impact on civilizations all around the world and are the greatest cause of death for people between the ages of 5 and 29. The United Nations Sustainable Development Goals include road safety as a critical development issue for all nations, particularly those in low- and middle-income countries.

Along with goals for maternal health, malaria, and HIV/AIDS, road safety targets are included in the health goal. They have also been aligned with the Sustainable Cities goal, along with goals for housing and air quality. The issue of road safety in Kenya, like in other low- and middle-income countries, has been exacerbated by the country's rapid population growth, both in terms of population and vehicle ownership. The entire Kenyan road traffic system is currently unable to handle the volume of traffic, which is resulting in a significant number of fatalities and major injuries (2021–2025 National Road Safety Action Plan). Road traffic systems have been allowed to develop without proper consideration of people's safety. Currently, roughly 3000 fatalities due to traffic accidents are officially recorded annually, but the health system records twice that amount, and there are reliable estimates of up to 12,000 fatalities. Tens of thousands more people sustain injury. The economic burden is severe.

As stated by Liu G. et al. (2018), there is a need for comprehensive research to identify the causes of road accidents, as they are a public health issue worldwide. Further, Liu et al. (2018) observed that there is a need to pay special attention to extremely serious road accidents (ESRAs). According to China's 2007 State Council Decree No. 493, ESRAs are defined as traffic incidents that result in more than 10 fatalities, more than 50 serious injuries, or more than 7.9 million yuan in direct economic losses.

ESRAs are caused by a variety of reasons. Liu G. et al. (2018) listed several of these factors, including fatigue, excessive speeding, and overloading. According to a study by Zhang, G., Yau, KKW, and Chen, G. (2013) on risk factors associated with traffic infractions and accident severity, overload poses a higher risk of serious accidents when combined with other traffic offenses. Fatal road accidents have become a daily phenomenon in Kenya. At least 13 people are killed on Kenyan roads daily — (NTSA data as reported on Daily Nation, Monday, January 27, 2025). Road accidents not only shatter families and devastate communities but also pose a significant economic burden on the nation. It is estimated that road carnage costs Kenya's economy a staggering Sh450 billion annually (National Road Safety Action Plan 2024-2028). According to statistics released by the NTSA, 3,581 fatalities were recorded from June 2024 to March 2025, a 10 percent increase compared to the 2023/24 financial year.

This is a clear indication of the inadequacy and gaps in the current methods used to control vehicle overloading. Traffic police officers (for enforcement of traffic laws**,** policies, such as the famous Michuki rules), agencies like the NTSA (created to develop and implement road safety strategies, regulate public service vehicles, among others), and Weigh Bridges (used for weighing vehicles and their loads) are examples of current methods for preventing vehicle overloading.

Figure 1

Overloaded Matatu

Source: www.alamy.com.

This project presents a microcontroller-based system designed to monitor and control vehicle overloading by detecting excess passengers and luggage. Load sensors installed beneath the vehicle’s chassis are used to measure its total weight. An infrared sensor placed at the vehicle's entry point counts the number of people entering. A microcontroller processes the collected data and compares it with predefined safety limits for both weight and passenger capacity. Suppose the total load or number of passengers exceeds the manufacturer's or legal limits. In that case, the system immediately displays a warning on an LCD screen and sends an SMS alert to the vehicle owner or relevant transport authority through a GSM module.

This system helps ensure that vehicles stay within safe loading limits by providing real-time monitoring. By keeping track of both passenger count and total weight it improves overall safety, reduces the risk of accidents, and helps prevent the extra wear and tear that often comes from overloading.

1.2 Problem Statement

Weight, rather than the amount of cargo space, determines a vehicle's load capacity. What many people are concerned with is the available cargo space, which is contrary to the tare weight. Overloading should not be determined by the number of passengers in the vehicle, but by the actual tare weight of the vehicle. The Traffic Act Cap 403, Kenya Section 56 states:

> *"No vehicle shall be used on a road with a load greater than the load specified by the manufacturer of the chassis of the vehicle or than the load capacity determined by an inspector under this Act" (Traffic Act Cap 403 Kenya, 2018)*

According to Clause 56 of Kenya's Traffic Act, Cap 403, the tare weight should be the actual determinant of overloading. However, in Kenya, law enforcers concentrate on the vehicle's cargo space, i.e., in the case of a PSV or a private vehicle, the number of passengers in the vehicle is used as the determinant of overloading. If the vehicle has a capacity of 1 ton or less, it is deemed to be compliant. This is erroneous. For stakeholders and drivers of Public Service Vehicles, be under no illusion.

Although you may have the correct number of passengers in your vehicle, there are instances where it canbe overloaded. Currently, bodies like weighbridge control units utilize technologies such as static weighbridges, weigh-in-motion (WIM) systems, RFID, and ANPR for vehicle identification, as well as cloud-based monitoring. While effective to an extent, these systems have several shortcomings. Static weighbridges require vehicles to stop, causing delays and congestion. WIM systems, though faster, can be less accurate due to vehicle movement and road conditions. Both systems are costly to install and maintain, especially in remote areas. Additionally, they can be bypassed by drivers using alternative routes, and some systems struggle to detect axle-specific overloads or cheating tactics, such as lifted axles. Environmental factors and inconsistent enforcement further limit the effectiveness of these measures.

Therefore, there is an urgent need to automate overload control to avoid disregarding traffic laws and inefficiencies in service delivery.

1.3 The study Objectives

This section presents the main and specific objectives of the study.

1.3.1 General Objective

Therefore, the goal of this project was to develop a model that prevents vehicle overloading using microcontroller technology.

1.3.2 The Specific Study Objectives

The specific objectives of the study include:

i. To investigate the weaknesses in the current systems for preventing vehicle overloading.
ii. To design a microcontroller-based model to prevent vehicle overloading.
iii. To implement a microcontroller-based model to prevent vehicle overloading
iv. To validate the microcontroller-based system to prevent overloading in vehicles.

1.4 Research Questions

The study aims to respond to the following queries:

i. What are the weaknesses in the current systems for preventing vehicle overloading in Kenya?
ii. What is a suitable design for a Microcontroller-Based Systemto prevent vehicle overloading in Kenya?
iii. How can a model based on a microcontroller be implemented to prevent vehicle overloading in Kenya?
iv. How can the implemented system to prevent vehicle overloading in Kenyabe validated?

1.5 Justification for the Study

The issue of road safety in Kenya, like in other low- and middle-income nations, has been exacerbated by the country's rapid population growth, both in terms of population and vehicle ownership. The entire Kenyan road traffic system is currently unable to handle the volume of traffic, which is resulting in a significant number of fatalities and major injuries (2021–2025 National Road Safety Action Plan). Road traffic systems have been allowed to develop without proper consideration for the safety of our people. Currently, roughly 3000 fatalities due to traffic accidents are officially recorded annually, but the health system records twice that amount, and there are reliable estimates of up to 12,000 fatalities. Tens of thousands more people sustain injury, and the economic burden is severe.

1.6 Significance of the Study

An overloaded vehicle is considered both a cost and a safety concern. The Kenyan government incurs costs ranging from Kes 20 million to Kes 300 million to construct a kilometer of tarmac road. This is a huge sum of money that would go to waste if the road does not last its lifespan due to overloaded vehicles, which are known to destroy the road. The deployment of an integrated microcontroller-based model for preventing vehicle overloading will save the government a significant amount of money, which can then be allocated to other critical sectors of the economy, such as health and education.The study would be of great significance to the National Transport and Safety Authority (NTSA), which was established through an Act of Parliament, Act Number 33 on 26th October 2012, to harmonize the operations of the key road transport departments and help in effectively managing the road transport sub-sector and minimizing loss of lives through road crashes. NTSA achieves its mandate through partnerships with the National Police Service and County Governments. The traffic police officers are deployed to enforce compliance, but they cannot be on the road all the time, as they cannot be present on every road.

Additionally, they lack the equipment to detect weight, and hence, most vehicles on the road are overloaded. Compared to these traditional methods of controlling vehicle overloading, the proposed model can respond quickly to cases of overloading, saving a significant amount of workforce, material, and financial resources. The study will contribute to the body of knowledge by providing a report on the misconception of overloading, which is often construed to mean the available cargo space, rather than the tare weight as indicated by the vehicle manufacturer and Kenyan law. The investors will benefit from this proposed model by recouping their investment value as overloading increases and bad roads lead to higher maintenance costs, as well as non-payment by insurance companies. This will reduce the number of road accidents and their associated negative impacts.

The study will focus on developing a model based on a microcontroller for overload detection and prevention in public service vehicles. It will not interfere with existing enforcement agencies in the industry, but will rather enhance their functioning to ensure compliance with all the rules and regulations in the industry.

1.7 The Scope of the Study

The primary goal of the project was to develop a microcontroller-based model for overload detection and prevention in public service vehicles. It will not interfere with the industry's current enforcement agencies, as all legal requirements will be adhered to before the system is deployed. This will enhance their effectiveness in ensuring that all established rules and regulations within the sector are adhered to.

1.8 Assumptions of the Study

a) The researcher assumed that the proposed model would be implemented in a real-life situation. However, this did not happen due to the stringent measures taken by the government to ensure the vehicle's functionality.

b) Government agencies such as KENIA and NAREF were involved as anticipated. However, since the system was not tested on a real vehicle, it was not included in the national road safety action plan for 2021-2025.

c) All other factors,such as speed, personnel, and vehicle condition, were considered constant and normal. This was to assist the researcher during the evaluation of the model. During deployment, the system will be fine-tuned to accommodate the real-life situation.

1.9 Limitations of the Study

In this study of developing a microcontroller-based model for overload detection and prevention in the transport industry, the researcher had foreseen some limitations, which included:

a) Legal issues -A significant limitation of this work is that on-road testing couldn't be conducted due to delays in obtaining approval from the NTSA. This means that how the system performs in real-life situations like handling vibrations, varying loads, and the dynamics of moving vehicles still needs to be confirmed. To mitigate this, we developed a bench-top prototype and tested it using simulated load inputs, while monitoring the microcontroller sensors. This helped us partially validate the system's functionality.

1.10 Ethical Considerations

- Safety - The system must be safe to use, as it involves transporting people to various destinations. The manufacturer of the system will bear responsibility in the event of an accident resulting from the system malfunctioning.
- The system should not drive people out of their businesses. In this regard, the affected individuals will be trained and assisted in transitioning to the new system.
- The system should be fitted in all vehicles without leaving out others to avoid unfair competition. The regulator will apply the law equally.

Evaluation of the Model

Make sure that data collection and analysis are done in an honest manner and that results are presented truthfully and without bias. Independent people will be asked to carry out the evaluation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The review of the literature pertinent to the investigation conducted is presented in this part. The review is based on the aforementioned research goals. The chapter also presents a discussion on overload detection and prevention process and the challenges facing the process in transport industry. Models for overload detection and prevention currently in use around the world are among the key issues reviewed and their challenges presented. The chapter also introduces Microcontroller technology and its suitability in the overload detection and prevention process based on the challenges described. The conceptual frameworks and model implementation overview for the study will also be presented and discussed.

2.2 Overloading and Safety Situation

2.2.1 Globally

Vehicle overload is a worldwide issue. The road transportation industry has experienced significant growth, but the overload management system has not kept pace, negatively affecting economic benefit (F. Heller et al., 2020). Overloaded transport is to blame for more than 80% of truck-related road traffic accidents, according to the Highway Bureau of the Chinese Ministry of Transport (Yi-Hsin et al., 2020). The Chinese government has implemented severe fines on offenders to address this issue, but once more, drivers overload even more to make up for the cost. Table 1 provides data and analysis on percentage of road traffic differences by income status. People living on low-income are about three times more likely to die in a road crash than those on high-income.

Table 1

Global Data on Road Safety

Income Status	% Population	% of Road Traffic Deaths	% of Registered Vehicles
High Income	15	7	40
Middle Income	76	80	59
Low Income	9	13	1

Source: "Decade of Action for Road Safety 2011-2020".

2.2.2 Regionally

According to data from the World Health Organization and other sources, Africa has the greatest fatality rate, with an estimated index of 25 to 34 deaths per 1,000,000 people (Muguro et al.2022). This is a result of many reasons, including massive infrastructural investment and rapid motorization (Ambak, 2020). Utilizing tools like speed cameras, traffic management focused on speed while also monitoring reckless driving, overloaded vehicles, and drivers' possession of proper identification. Additionally, other measures are being implemented, including safe crossing locations, bicycle lanes, and sidewalks.

2.2.3 Road Trauma in Kenya

Our issue with road safety in Kenya, as in other low- and middle-income countries, has been exacerbated by the country's rapid population growth, both in terms of people and automobiles. The entire Kenyan road traffic system is currently unable to handle the volume of traffic, which is resulting in a significant number of fatalities and major injuries. Table 2 summarizes the impact of road traffic injuries (RTIs) as a leading cause of death and disability in Kenya, broken down by key population groups:

Table 2

Road Traffic Injuries in Kenya: Impact by Population Group (2024)

Population Group	Estimated Deaths (2024)	% of Total Deaths
15-24 years	1168	24.6
25-34 years	468	9.8
35-44 years	408	8.6
45-54 years	387	8.2
55-64 years	276	5.8

Source: Institute for Health Metrics and Evaluation (IHME)

2.2.4 Vehicle Overloading

Carrying more weight than is allowed is known as overloading, as each vehicle is made to carry only a certain amount of weight. It is a significant issue in both developed and developing nations worldwide (Gaira et al., 2020). Transport companies expect to increase their revenues by overloading their vehicles. Unfortunately, the risks exceed the advantages.

2.2.5 Effects of Vehicle Overloading

Overloading poses the following concerns, according to Vosa and Operator Services Agency:

a) It reduces vehicle stability, makes steering challenging, and lengthens stopping distances. When the maximum weights that they are designed to carry are exceeded, vehicles behave differently, and the results can be fatal.

b) Vehicle tires are put under much stress. The risk of an early, costly, and potentially deadly failure (such as blowouts) increases with overload, as it can cause the tires to overheat and degrade rapidly.

c) At the expense of the taxpaying public, it results in excessive wear and damage to pavements, bridges, and roads.

d) It is unjust to the competing operators. As more weight is transported on each trip, exceeding weight restrictions constitutes unfair competition.

e) Carrying more weight increases fuel consumption, which raises your prices.

f) Insurance coverage is invalid.

2.2.6 Causes of Vehicle Overloading

The following are the main causes of overloading:

a) It's not difficult to overload a car, and often drivers aren't even aware that their cars are overloaded. Be aware that even if your bus or coach has the right number of passengers inside, there are circumstances in which it may also be overloaded. This is important information for operators and drivers of public commercial vehicles.

b) The need for the driver and conductor of the matatu to make extra money, which often never reaches the owner.

2.3 Existing Models Used in the Prevention of Vehicle Overloading

The automotive sector plays a vital role in facilitating the movement of goods and people across various regions. Additionally, it provides vital support to various other industries within the economy. Implementing safety measures is essential for maintaining a reliable workforce and ensuring the ongoing success of other economic sectors. Through coordinated, multi-sectoral solutions to the issue, several nations, including Australia, Canada, France, the Netherlands, Sweden, and the United Kingdom, have experienced steady declines in the frequency of fatal traffic accidents. This section presents various overload detection and prevention models in use worldwide and the challenges encountered in their day-to-day application.

a) Virtual Weighbridge Systems

The KENHA report 2021/2022 presents Kenya’s adoption of Virtual Weigh Stations (VWS) as part of its weigh-in-motion strategy to continuously monitor axle loads without stopping vehicles. It details the integration of virtual weigh bridge systems within KeNHA’s axle-load control framework.The deployed virtual stations combine high-speed WIM sensors, Automatic Number Plate Recognition (ANPR), and a centralized management backend to identify and flag overloaded vehicles in real time and direct enforcement resources. They are intended to reduce manual static weighing and speed up enforcement (kenha.co.ke).

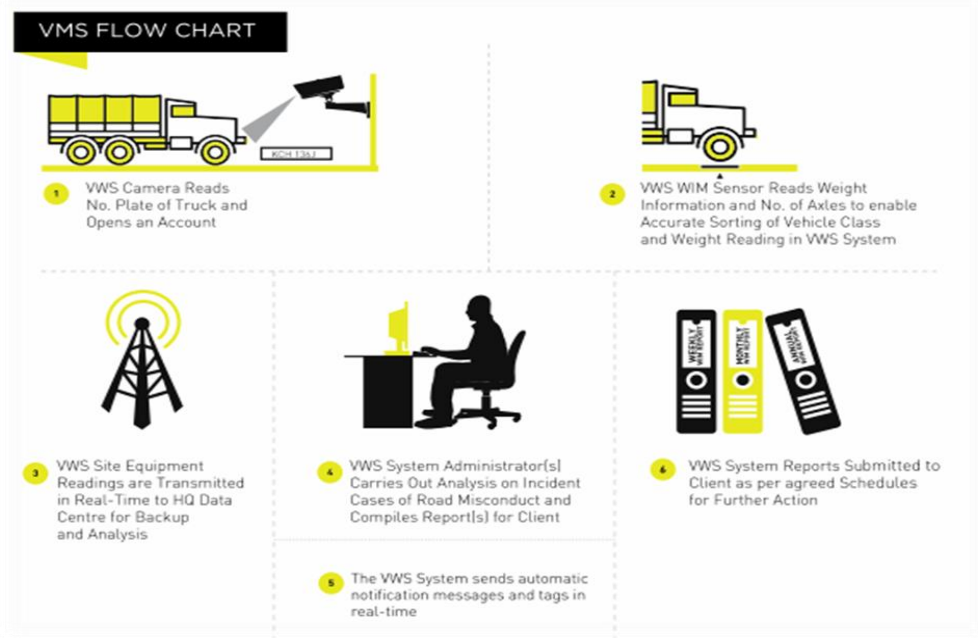
Many studies have examined the accuracy and reliability of Weigh-in-Motion (WIM) systems, especially when used for critical applications such as traffic enforcement, where precision is non-negotiable. For instance, Burnos et al. (2021) showed that high-accuracy WIM systems are indeed possible, but only when supported by detailed environmental monitoring. Their research highlighted that factors like pavement temperature, humidity, wind, and vehicle speed all play a significant role in measurement accuracy. Building on this, another study introduced the idea of "accuracy maps"—essentially operational zones that define where WIM measurements remain reliable. These maps suggest that enforcement-grade WIM systems should only be used within well-calibrated environmental and operational ranges.

Mechanical factors also play a significant role in determining the accuracy of WIM systems. A study on pavement mechanics revealed that the stiffness of the subgrade and the placement of sensors in the road surface directly affect the accuracy of axle load measurements. Poor sensor installation or road surface deterioration can introduce consistent errors. At Purdue University, researcher Nichols proposed using statistical tools such as residual analysis and tracking certain "characteristic" vehicles—to detect sensor drift and maintain the system's accuracy over time. When WIM systems are compared to static scales and portable weigh pads, they tend to offer better efficiency and broader coverage. However, they also come with a higher chance of measurement error particularly when it comes to vehicles with multiple axles or those that are dynamically unstable. Interestingly, WIM systems are generally more accurate at capturing gross vehicle weight than individual axle loads, which are more sensitive to factors such as speed changes, uneven load distribution, and suspension types.

Taken together, these findings make one thing clear: to rely on WIM systems for enforcement purposes, agencies must invest in ongoing calibration, environmental compensation strategies, and strong quality assurance protocols. Only then can WIM systems deliver the level of reliability that enforcement demands.

Figure 2

VWS Flow Chart



Source: KeNHA Report, (2021/2022)

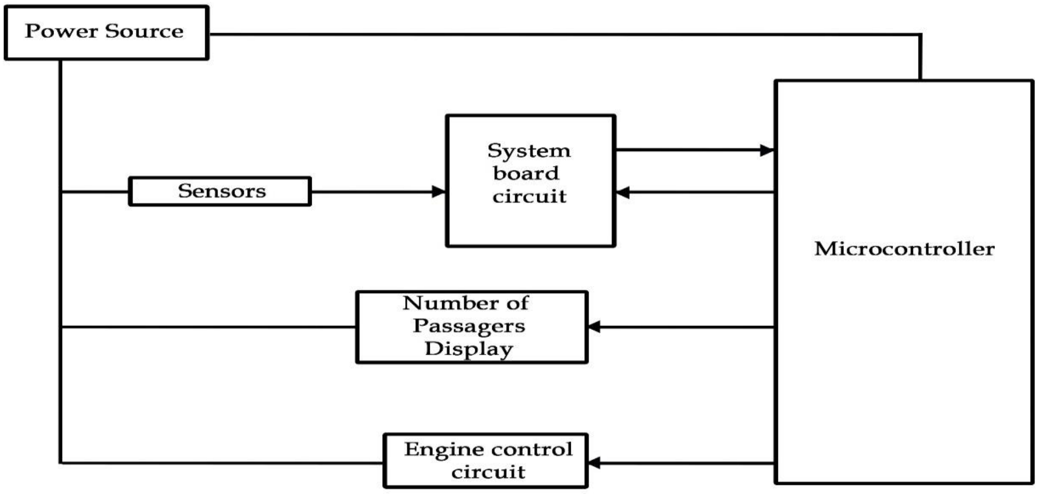
b) **IoT-Based Vehicle Monitoring Systems**.

Recent advances in IoT-based vehicle monitoring systems showcase the real-world benefits of wireless connectivity and real-time data handling in mobile settings. For example, Egwuonwu et al. (2021) developed a 4G/LTE-enabled system using a Raspberry Pi, GPS, and accelerometer to track vehicle speed, location, and condition. This data was sent in real time to a remote server, allowing for timely vehicle tracking and status updates. Similarly, Zulkifli et al. (2024) designed a low-power solution that utilizes LoRa communication, combined with GPS and vibration sensors, to monitor engine activity and vehicle movement, with a focus on community-level security needs. Although their LoRa system faced some signal delays and occasional reliability issues, it excelled in conserving power and reducing operational costs. In a broader comparison, Stăncel and Stoica (2024) evaluated various low-power wide-area network technologies for vehicle monitoring, finding that LoRa offers the best range and energy efficiency, despite its lower data speeds.

Taken together, these examples highlight how IoT vehicle monitoring systems offer greater flexibility than traditional Weigh-in-Motion (WIM) setups, which rely on fixed road sensors that are expensive to install and maintain. Unlike the static nature of WIM infrastructure, IoT systems can be deployed with minimal disruption, provide remote diagnostics, and continuously monitor vehicles across a wide area. Their modular design also makes them ideal for adapting to different needs, such as fleet management, theft prevention, or engine diagnostics. This makes IoT monitoring especially valuable in rural or resource-limited regions where installing conventional WIM systems would be difficult or too costly.

Figure 3

Block Diagram For Vehicle-Mounted Excessive Passenger Loading Control System



c) Vision-based Weigh-in-Motion (V-WIM)

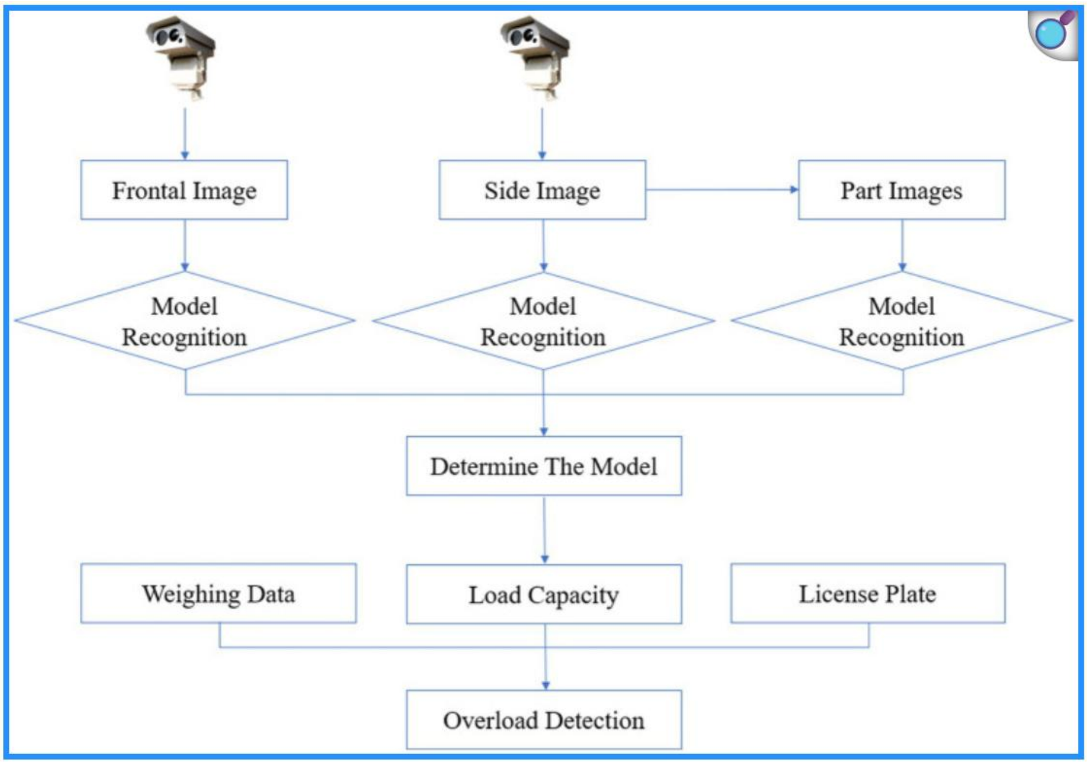
Recent developments in Vision-based Weigh-in-Motion (V-WIM) systems are showing real promise in improving how we estimate vehicle weight, thanks to advances in camera technology and data fusion techniques. For example, Lam et al. (2025) introduced a deep learning–based V-WIM system that utilizes object detection (YOLOv8) and tracking (Byte Track) to identify vehicles and analyze tire deformation, allowing for accurate weight estimation without requiring pavement cuts. Similarly, Zhou et al. (2023) combined roadside cameras with in-road GFRP-FBG sensors to correct for wheel wander, a common source of error in traditional WIM setups.

Their approach boosted axle load accuracy to as high as 94.7%. In another study, Tang et al. (2024) addressed the issue of dynamic vehicle movement, utilizing camera footage to track wheel oscillations and enhance weight accuracy. Their method reduced error from 60% down to just 15% in challenging conditions. Together, these studies highlight the growing effectiveness of hybrid systems that combine visual data with traditional sensors particularly in handling complex, real-world factors such as wheel misalignment and suspension motion. With proper calibration and quality control, V-WIM systems could become a viable option for enforcement-grade weight monitoring in the near future.

This paper introduces a novel method for detecting truck overloading. The method utilizes the improved MMAL-Net for truck model recognition. Vehicle identification involves using frontal and side truck images, while APPM is applied for local segmentation of the side image to recognize individual parts. The proposed method analyzes the captured images to precisely identify the models of trucks passing through automatic weighing stations on the highway.

Figure 4

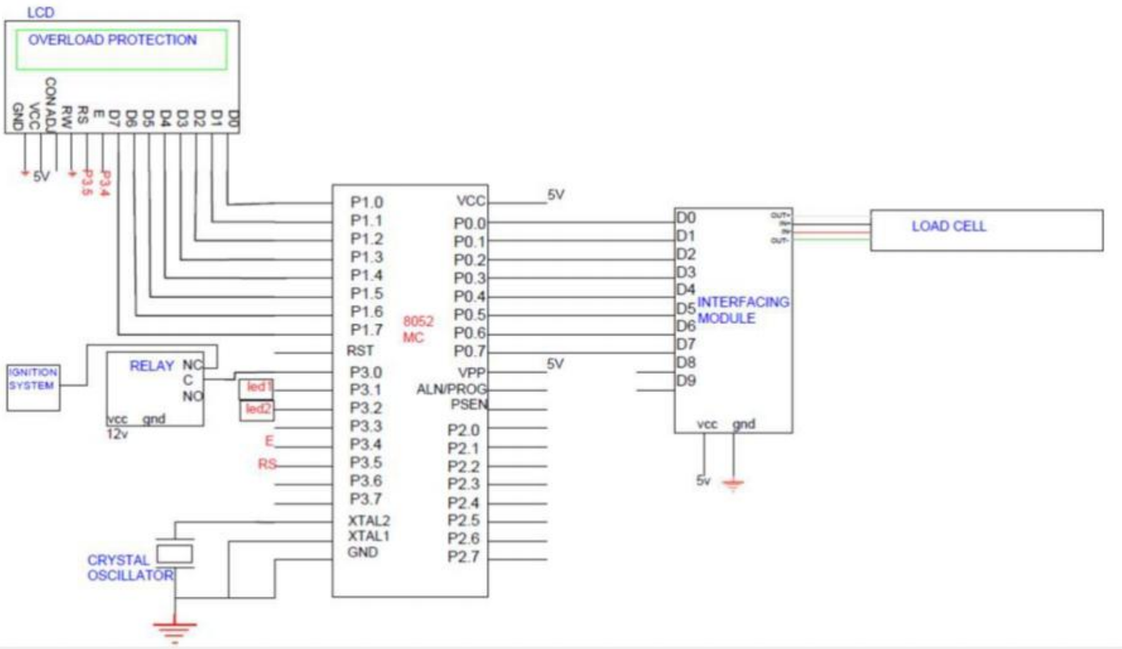
Block Diagram for Truck Model Recognition for an Automatic Overload Detection



Source: Zhou et al.(2023)

Figure 5

Circuit Diagram Truck Model Recognition for an Automatic Overload Detection System



Vehicles transport both people and goods. Each of these has its limit beyond which one would be considered as contravening the Traffic Act. For compliance purposes, the system should be able to detect and control excess passengers and goods. This system,Which Utilizes Truck model recognition for an automatic overload detection system, suffers from the limitation of only detecting overload in terms of goods, rather than passengers' overload.

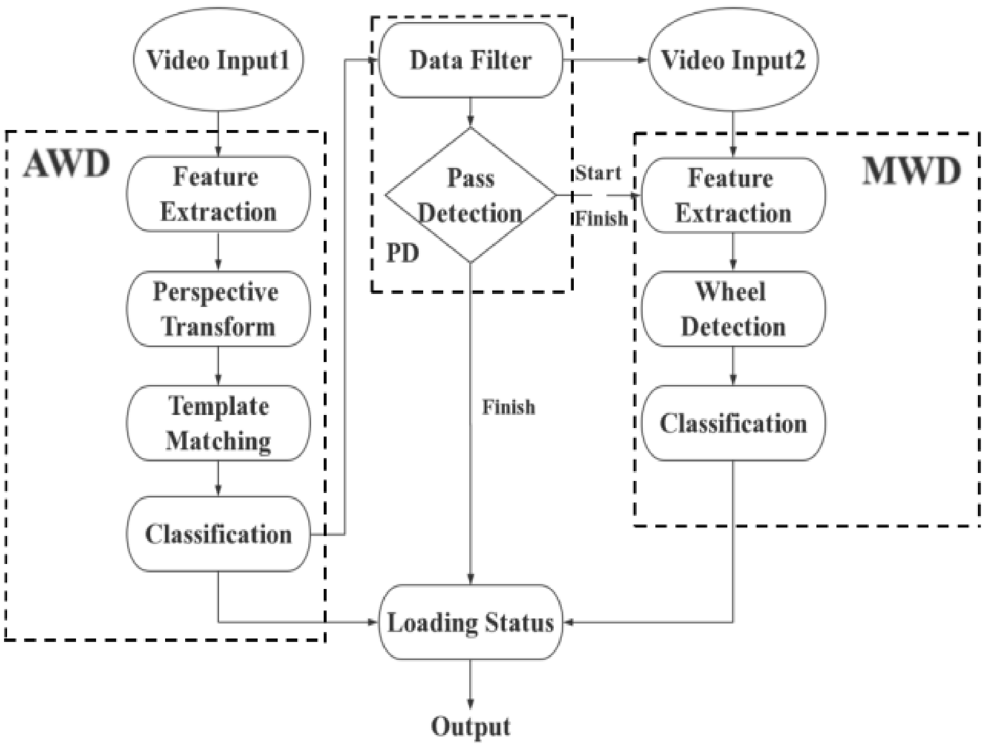
d) Sensor Data Fusion in Multi-Sensor Weigh-In-Motion Systems

Sensor data fusion has become a key strategy for enhancing the accuracy of Weigh-in-Motion (WIM) systems, particularly under dynamic conditions where noise and uncertainty can significantly impact measurement reliability. Gajda, Sroka, and Burnos (2020) investigated a multi-sensor WIM (MS-WIM) system equipped with 16 in-road sensors and evaluated the impact of different estimation methods on the accuracy of gross vehicle weight (GVW) and axle load measurements. They compared a simple averaging method with a maximum likelihood estimator (MLE) that accounts for individual sensor uncertainties. Their findings showed that the MLE consistently outperformed the basic averaging approach, yielding more stable and precise weight estimates particularly in scenarios where sensor quality varied.

The results held true in both simulation and real-world tests using reference vehicles under varying speeds and environmental conditions. This study highlights the value of intelligent data fusion techniques in WIM applications, as they help mitigate the effects of sensor noise, pavement dynamics, and vehicle variability. Incorporating such estimators into enforcement-grade systems could support better adherence to accuracy standards and extend the operational reliability of WIM infrastructure.

Figure 6

Block Diagram for A Vision-based Overload Detection System for Land Transportation



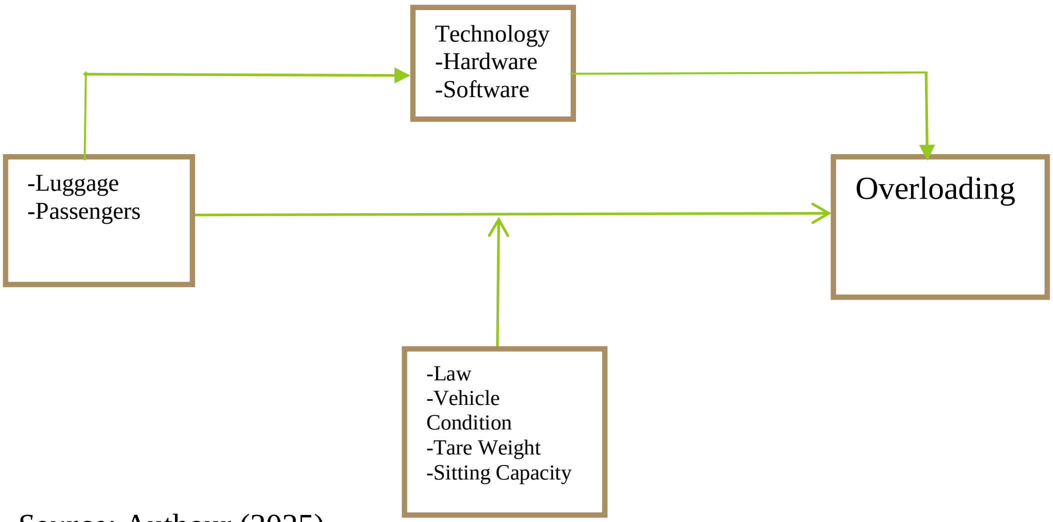
Source: CICTP (2020)

2.4 Conceptual Framework

Figure 7

Conceptual Framework

Independent Variable Moderating Variable Dependent Variable



Source: Authour (2025)

2.5 Research Gaps

Vehicle overloading is a relatively common occurrence, and enforcement initiatives have largely proven to be ineffective. Road surfaces are damaged, and these cars are involved in more collisions than those loaded in accordance with their requirements. The collisions that do occur are also more likely to be fatal. Fewer than 10% of emerging nations have any efficient vehicle weight control programs. The sheer lack of straightforward, dependable, and affordable weighing equipment is a fundamental factor in the weaknesses of these programs.

2.5.1 Weaknesses of Current Systems Used to Prevent Vehicle Overloading

Overloading a vehicle is an unlawful offense in Kenya. The following are the penalties for faulty condition or overloading as stated in Section 58 of the Traffic Act Cap 403:

> *"Any person who drives or uses on a road a vehicle in contravention of the provisions of section 55, 56 or 57 or in accordance with the East African Community Vehicle Load Control Act, 2013, shall be guilty of an offence and*

liable to a fine not exceeding four hundred thousand or to imprisonment for a term not exceeding two years or to both:"

Although this act has been enacted, it has not been effective due to the rampant corruption on the part of the traffic police officers and the concerned drivers. There are also other rules, such as the famous Michuki rules (Traffic (Amendment) Rules, 2003), which reduced the carrying capacity of public service vehicles, required the installation of speed governors, and mandated the indication of the carrying capacity of each vehicle on the vehicle's body. These measures were all targeted at public service vehicles, excluding other types of vehicles that also suffer from overloading. The NTSA and the traffic force are mandated by law to ensure safety and enforce the rules. These agencies are stationed at specific parts of the road, where they cannot be present twenty-four hours a day due to weather and other issues. They are also only concerned with cargo space because they lack the necessary equipment to ensure the correct weight. Weigh bridges are only used for vehicles that weigh seven tons or more.

Again, these weighing bridges are located at specific sites that can be avoided by overloaded vehicles. In Kenya, there were 2,989,788 registered automobiles as of the end of 2017, according to information from the Kenya National Bureau of Statistics. In 2018, the number increased to 3,280,934, representing a rise of 291,146 people, or nearly 10% more people every year. President Uhuru Kenyatta's speech, addressed to the National Police Service on 16 January 2017, link, called attention to the 98,732 law enforcement personnel tasked with ensuring compliance. As a result, there are not enough police officers in the nation to implement these laws.

Road transport networks, despite their significant economic contribution, might incur significant expenses when they lack capacity or dependability (Rodrigue, J-P et al., 2020). For instance, a poor transportation system can lead to financial expenses, such as lost or reduced opportunities, and a lower standard of living in the event of accidents. The Global Status Report on Road Safety, published by the World Health Organization in 2018, states that road traffic injuries remain the largest cause of death, accounting for approximately 1.35 million fatalities per year. Kenya is included in the low- and middle-income countries where almost 90% of these fatalities take place.

From the study of the existing models discussed in section 2.3, it was noted that there are gaps in these models. Table 3 below gives a summary of these gaps.

Table 3

Gaps in Existing Model

Policy & Model	Objective	Benefits	Gaps
Traffic Act Cap 403 Section 58	To prevent overloading of Vehicle	No vehicle shall be used on the road while overloaded	-Requires human capital to enforce -Majority of road users are not aware of this act. -Lack of equipment to detect weight.
Michuki Rules Traffic (Amendment) **Rules**, 2003. 2 ... JOHN **MICHUKI**, Minister for Transport and Communications.	Prevents road accidents in PSV	-Installation of speed governors -Reduced number of passengers in a matatu	- Requires human capital to enforce -Targeted only PSVs -Weight not considered
High Accuracy Weigh-In-Motion Systems for Direct Enforcement. (Burnos et al.2021) Poland	Prevent overloading of	Improve on the accuracy of the instrument	-By-pass risk -Complexity -Cost is high -Environmental sensitivity -Installation challenges
IoT-based passengers overload monitoring and reporting system. (Natarajan, Balakrishnan, et al 2024).	Detect and prevent carrying of excess luggage	-Prevent damaging of the road and vehicle - Enhance safety - Reduce the likelihood of accidents.	-Does not consider the number of passengers. -Sensor accuracy & false counts -Connectivity & latency - Power & durability -Scalability & privacy
Truck model recognition for an automatic overload detection system (Zhou., et al. 2023)	Prevents overloading of luggage	-Prevent damage of the road -Identify truck make	-Does not consider overloading of passengers -Compute, cost and privacy tradeoffs - Environmental and occlusion sensitivity -Vision-only inference of load is indirect and error-prone
A Vision-based Overload Detection System for Land Transportation Wang, Y. et al., (CICTP 2020)	Prevent carrying of excess passengers	-Prevent carrying of excess passengers - Indirect inference of load - Sensitive to lighting	- Indirect inference of load - Sensitive to environmental factors -Occlusion -Obstruction -Privacy issues -still emerging
Virtual Weighbridge Systems (KENHA REPORT 2021/2022)	Prevent damage of road	-Prevent damage of road	-Overloading of passengers not considered -Limited coverage. -Easy to evade -High installation cost - maintenance-intensive - Enforcement issues -Reactive - Calibration, accuracy & environmental sensitivity

2.6 Design of Microcontroller-Based Integrated Model for Vehicle Overload Detection

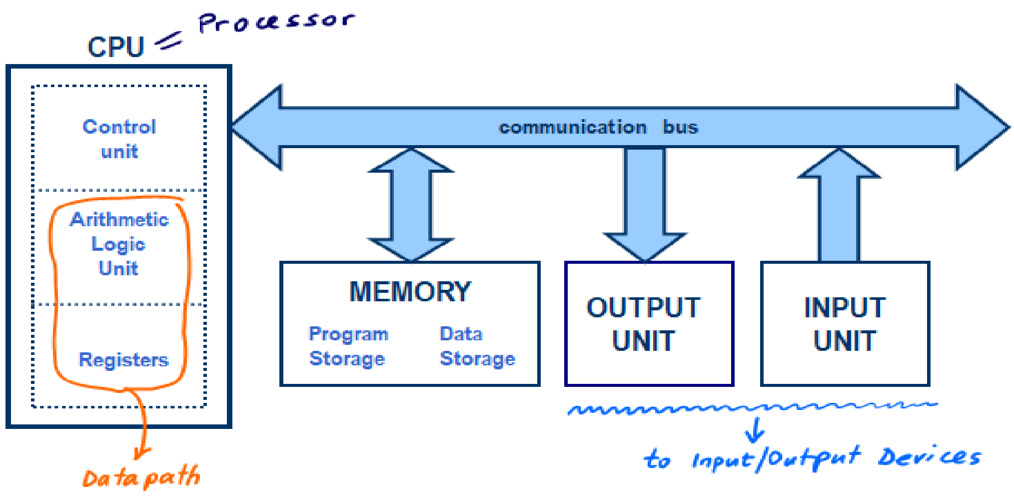
The significant potential for revenue generation from the motor vehicle sector and its function as a supporter of other economic areas cannot be understated. Therefore, it is crucial to have effective regulations in place to harness this potential. More importantly, there is a need to prioritize road safety and the protection of all individuals using the roads. Any revenue losses incurred during this collection process can adversely affect the country's economic growth, underscoring the need to address the identified issues. An effective preventive framework could be enhanced by developing an integrated model that utilizes microcontroller technology to actively mitigate vehicle overloading. The suggested model will comprise various components: Control Unit, Display Unit, Weight sensor, IR Sensors, and Motor drive, which are elaborated on in this section.

2.6.1 Microcontroller Overview

An embedded system can use a microcontroller, which is a compact, inexpensive, and self-contained computer on a chip (Utkir, 2020). It is composed of: a Microprocessor (CPU), ROM (for software), and RAM (for data), as Well as Peripheral devices (to facilitate implementing the necessary functionalities) and I/O ports (to interact with and communicate with external resources).

Figure 8

Microprocessor



Source: Utkir, (2020)

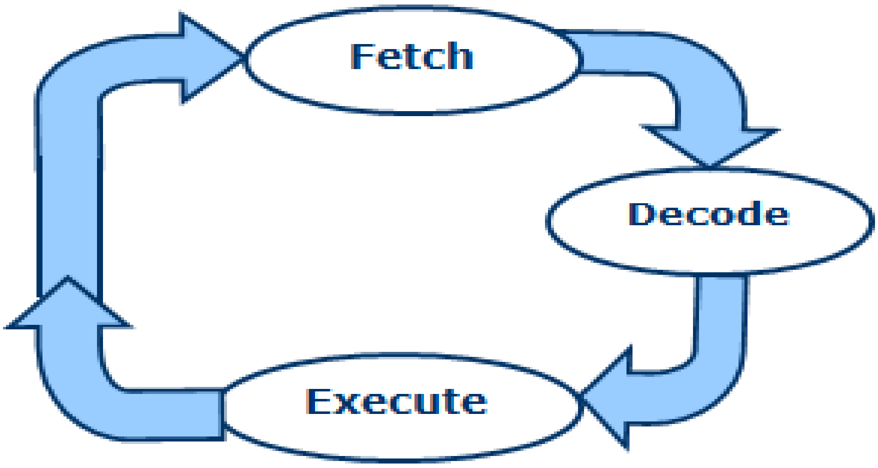
A microcontroller is like a Swiss Army knife, as it has numerous functionalities built into a single Integrated Circuit. The block diagram above illustrates a typical microcontroller, which is essentially a computer on a chip. The design includes the ALU, PC, SP, and registers found in a microprocessor CPU. A complete computer must also have the following features: ROM, RAM, Parallel I/O, Serial I/O, Counters, and Clock Circuits. A microcontroller is a general-purpose device, similar to the microprocessor, except it is designed to read input, make a limited number of computations with that data, and then control its surroundings based on those results. The primary function of a microcontroller is to regulate a machine's operation using a fixed program stored in ROM, which remains constant throughout the system's lifespan. (Kenneth J. Ayala, The 8051 Microcontroller).

2.6.2 Basic Operation of a Microprocessor

Data and Program (instructions) are kept in Memory. Each instruction is read (fetched) from memory, decoded (interpreted), and executed. The Arithmetic Logic Unit (ALU) then executes operations on the data. The Program Counter (PC) is automatically incremented after each instruction and displays the current location of the program in memory. Each instruction can require a number of clock cycles.

Figure 9

Block Diagram of fetch-execution cycle



Source: Utkir (2020)

2.6.3 Common Applications

a) Automobiles:

i) safety features (airbags, automatic brakes),

ii) engine management (exhausts, ignition), and

iii) power windows

b) Telephone systems and automated answering systems

   i) Cell phones and pagers

   ii) Networking (Ethernet, ATMs, credit cards)

c) Consumer:

Consumer items include a washing machine, a remote control, a clock or watch, a game or toy, and an audio or video device.

d) Military:

Systems for the military that include target recognition systems, guidance systems, and global positioning systems

e) Industrial: inventory and stock management, robotics, production facilities, and traffic control, and robotics.

f) Health: Cardiac monitors, renal monitors, pacemakers, and dialyzers are just a few examples.

2.6.4 Components of the Integrated Model

i) Sensor

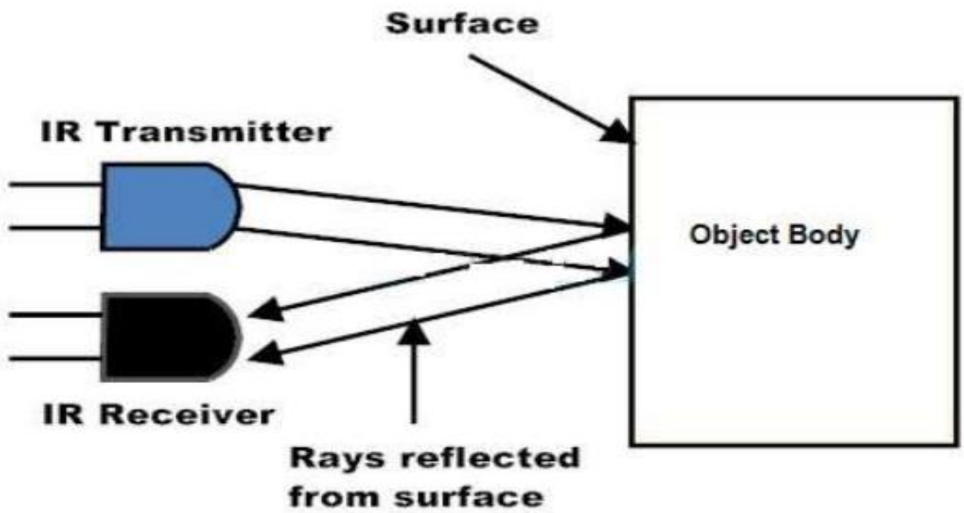
A sensor is a device that receives a signal or stimulus and responds to it by emitting an electrical signal, according to Khairudin et al. (2020). The sensor is a device that processes a variety of signals, including physical, chemical, and biological inputs, into an electric signal. The sensors are categorized into various types based on their applications, input signal, conversion technique, material used, and sensor characteristics such as cost, accuracy, or range. This study will use an infrared sensor and a weight sensor, two distinct types of sensors.

i. Infrared Sensor

According to Khairudin et al. (2020), an infrared (IR) sensor consists of two packets: the Rx (receiver) and the Tx (transmitter). The infrared spectrum is sent by transmitters and received by receivers. Before it emits photons in the IR band, a voltage is supplied between its terminals. The main premise of an IR sensor is object reflectivity. When an object is placed in front of the IR transmitter, the rays coming from the IR receiver have a propensity to reflect off it. A voltage level is created across the terminal when the receiver detects a beam that was reflected by an object. The amount of light reflected by the object determines the voltage level. The IR transmitter emits a signal over a particular distance and within a specific range when the transmitter and receiver are placed side by side. Some IR rays that come into contact with a surface will reflect, depending on the color of the surface. Because more IR rays are absorbed by a darker surface, more IR rays are reflected when a color is brighter, and fewer IR rays are reflected when a surface is darker.

Figure 10

IR Sensor Diagram



Source: Research Gate

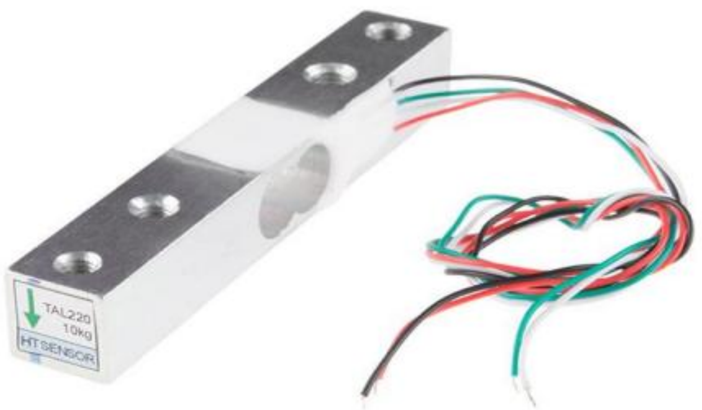
i. *Weight sensor*

According to Smith (2020), a load cell is essentially a force transducer or force sensor. It is primarily used to measure weight. The researcher will focus on weight measurement applications in this research, although they can also be used to measure other forces, such as torque, compression, and pressure. Pneumatic load cells, which are frequently used in intrinsic safety applications, are just one of the fundamental technologies employed in load cells. Since hydraulic load cells don't need electricity, they are widely employed in isolated, difficult-to-reach sites. Additionally, there are strain-gage-based load cells and piezoelectric load cells that produce high-level (yet non-linear) outputs.

Since strain-gage-based load cells are the most widely used today, this study will concentrate on them. They can manage a variety of force inputs and are affordable, dependable, and readily available. They offer a full-scale accuracy of 0.25% or greater and are the de facto industry standard.

Figure 11

Diagram for Load Cell



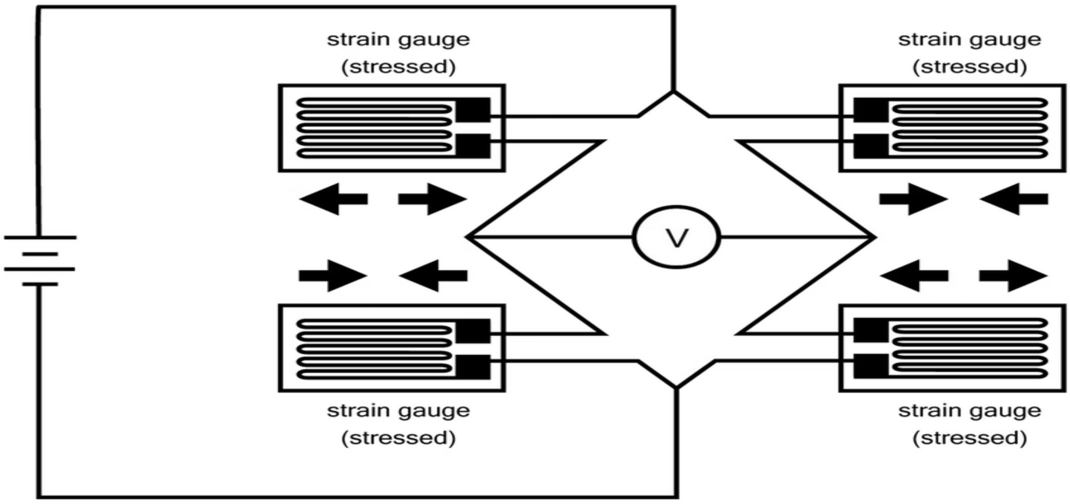
Source: Scalenet.com

iii. An Overview of a Strain Gage-Based Load Cell's Operation

A strain gauge measures strain by detecting a change in resistance. An insulator and flexible substrate combination is applied with a metal foil design. The foil design is subjected to an electric current. According to the amount of deflection, there is a change in resistance when the object being tested is stressed (i.e., compressed or put under tension) (Zhang et al., 2019).

Figure 12

Full Bridge Strain Gauge Sensor



Source: Smith, (2020)

b) Display Unit

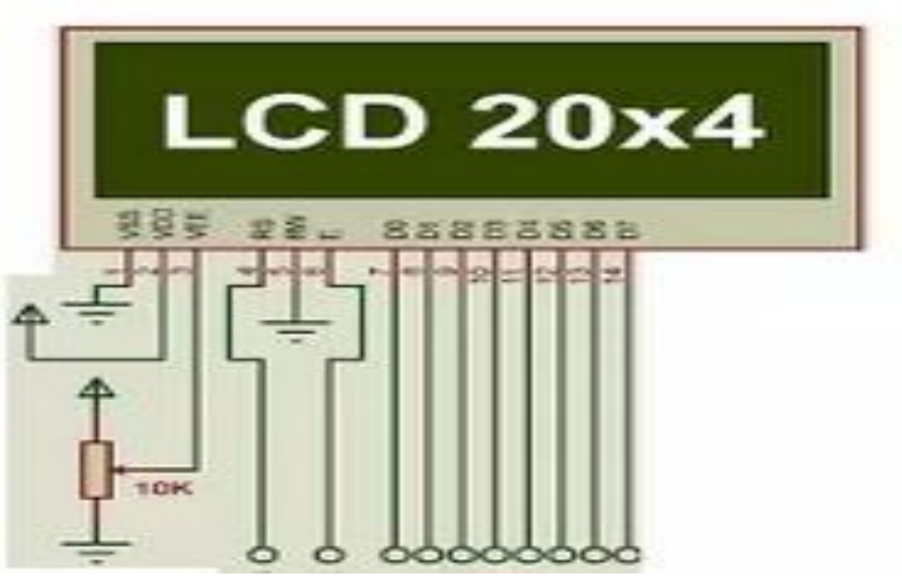
CRTs, plasma displays, LCDs, LEDs, 7-segment displays, OLEDs, and FOLEDs, as well as digital light processing and e-books, are just a few of the various display devices available. Because it will be used, the 20x4 LCD will be covered in this section.

i. LCD Display

Liquid crystal display (LCD) screens are electronic display modules with a variety of applications (Williamjones, 2019). A 20x4 LCD display is a fundamental module that is frequently used in various devices and circuits. These modules are preferable over multi-segment LEDs with seven segments and additional segments. The rationales behind this are that LCDs are inexpensive, easily programmable, and do not have any restrictions on the display of animations, special characters, or even bespoke characters (unlike seven-segment displays). Twenty characters can be displayed on each of the four lines of a 20x4 LCD, which can display 20 characters per line. Each character on this LCD is presented using a 5x7 pixel matrix. The Command and Data registers on this LCD are its two registers. The command instructions sent to the LCD are stored in the command register. A command is a directive issued to an LCD device to perform a specific operation, such as initializing it, clearing its screen, adjusting the cursor, or managing the display. The data displayed on the LCD is stored in the data register. The character's ASCII value, which will be displayed on the LCD, is the data.

Figure 13

20x4 LCD Pinout



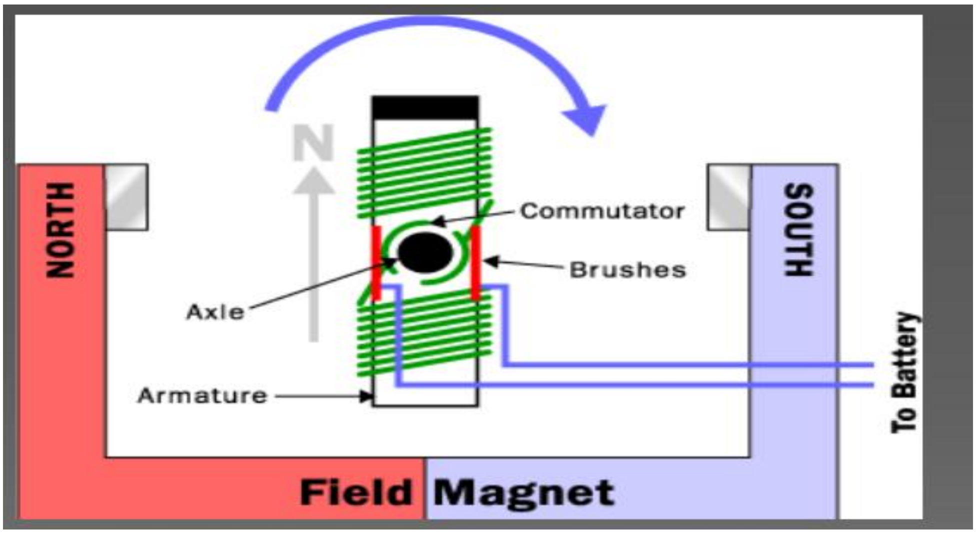
Source: www.TheEngineeringProjects.com

c) DC Motors

DC motors will be employed in this model. The armature, which is mounted on the rotor, and the field poles, which are immovable, make up a DC motor. Except for permanent magnet motors, all DC motors must carry current to the armature windings by passing it through carbon brushes that move over a commutator, a collection of copper surfaces located on the rotor. The commutator bars and armature coils are soldered together. Based on the rotor's location, the brush/commutator assembly creates a sliding switch that powers up specific areas of the armature. By running direct current through the field windings to make the north and south magnetic poles on the stator, this procedure produces north and south magnetic poles on the rotor that are drawn to or repelled by the same poles on the stator. The rotor rotates as a result of this magnetic attraction and repulsion (Indragandhi et al., 2022, p 505).

Figure 14

Parts of an Electric Motor



Source: Electric Motor Drives and their Applications

d) GSM

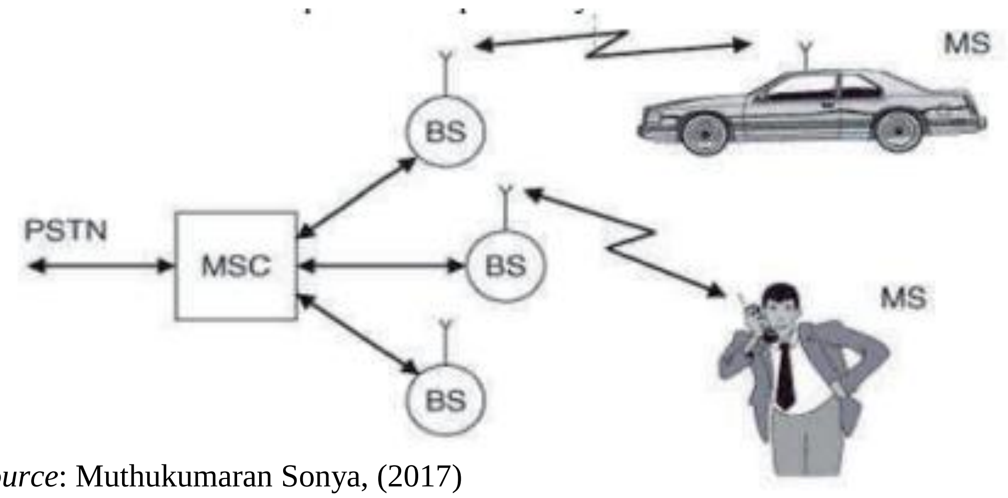
Global System for Mobile Communications, or GSM. Mobile voice and data services are transmitted using this digital cellular technology. SMART AGRICULTURE, 2019 (Internet of Things (IoT).

Composition of the Network

Hardware is used to connect the mobile device to the network. The network receives identification data about the mobile user from the subscriber identity module (SIM) card**.**

Figure 15

Principle of a Cellular System



Source: Muthukumaran Sonya, (2017)

Cell phone traffic is handled by the Base Station (BS), also known as the Mobile Station (MS). The base transceiver station (BTS) and base station controller (BSC) are its two primary parts. The BSC is the brains behind the BTS, which houses the hardware that interacts with mobile phones, primarily the radio transmitters, receivers, and antennas. The base transceiver stations are managed and communicated with the BSC. To facilitate the delivery of cellular services, the NSS component of the GSM network architecture, also known as the core network, tracks the position of callers. Mobile operators own the NSS. The Mobile Switching Center (MSC) and Home Location Register (HLR) are just two of the components that make up the NSS. These parts perform a variety of tasks, including SMS and call routing, caller authentication, and storing caller account information.

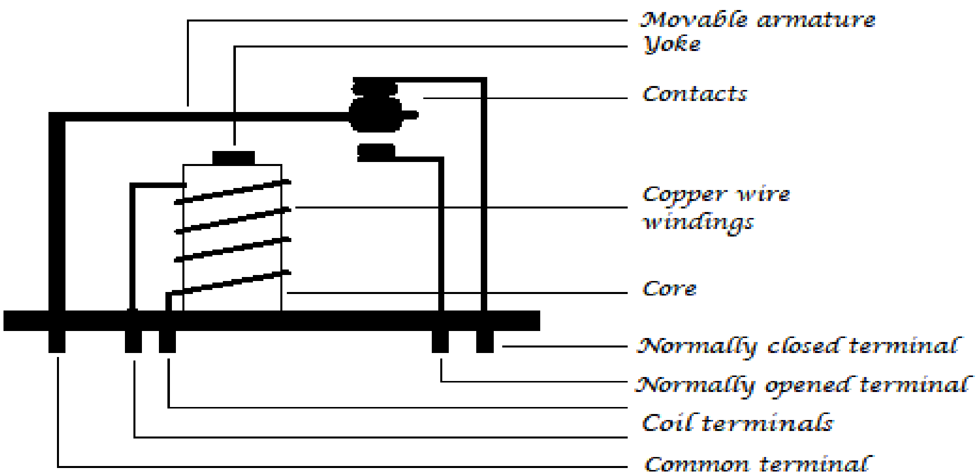
e) Relay

An electromechanical device called a relay can be used to establish or sever an electrical connection. A relay is essentially a mechanical switch that can be controlled electronically via an electromagnet, as opposed to being manually turned on or off. It consists of a flexible, movable mechanical component. (I.Kaur 2010). A basic, widely used relay is composed of electromagnets and is typically employed as a switch. Relays come in various types, each with its own specific purpose. This device can be described as a relay since the signal received from one side of the device controls the switching activity on the other. According to the dictionary, relay refers to the act of transmitting something from one item to another. A relay is a switch that electromechanically controls (opens and closes) circuits. This device's primary function is to establish or break contact with the aid of a signal, without the need for human intervention, to turn it on or off. It is primarily used to employ a low-power signal to operate a high-power circuit. Typically, a DC signal is used to operate a circuit powered by high voltage, such as when using microcontrollers to control AC home appliances.

The interior layout and construction of a relay are shown in the following figure.

Figure 16

An Electromechanical Relay



F) Logic Gates

Transistors are the fundamental building blocks of an integrated circuit (IC), and they are used to create logic gates. Digital systems are designed using logic gates; the three basic logic operations are AND, OR, and NOT. A function or truth table can be used to represent the characteristics of a digital system. In order to require fewer logic gates, Boolean functions are made simpler using Boolean theorems. According to the number of gates they contain, integrated circuits are divided into four categories: SSI, MSI, LSI, and VLSI (Elahi, 2018).

Several fundamental logic gates are used in digital systems to perform operations. The typical ones are the OR gate, AND gate, and NOT gate.

g. The XOR Gate

These gates can also be discovered in pairs or combinations of one or two. As a result, we also obtain gates such as the NAND, NOR, EXOR, and EXNOR gates.

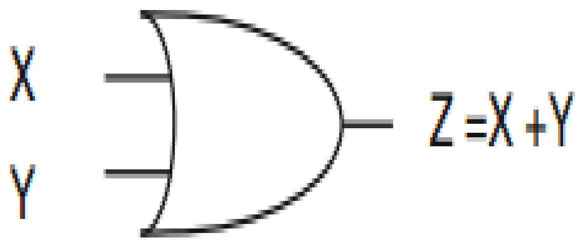
a) The OR Gate

The plus sign, "+," or a V are used to indicate the OR operation, with "+" being the more common choice. You pronounce X + Y as X OR Y.

Z=1 if X=1ORY=1 or both X and Y are 1 and X+Y=Z:

Figure 17

Symbol of a 2- 2-Input OR Gate



Source: (Elahi, 2018, p. 31)

The OR gate's Boolean statement is Y = A + B, which can be translated as Y equals A 'OR' B.

The truth table for a two-input OR basic gate is displayed in Table 1 below.

Table 4

OR Gate Truth

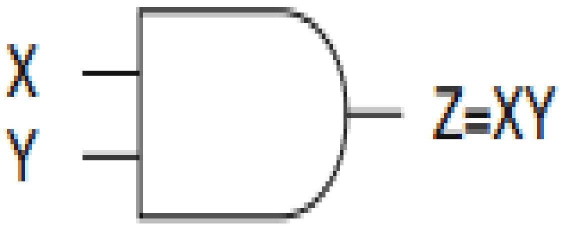
X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

b) *AND Gate*

The AND logic is indicated by the period ".," though this is typically omitted. If X=1 and Y=1, then Z=1; otherwise, Z=0. X.Y or XY is pronounced as X AND Y.X AND Y=Z.

Figure 18

Symbol of a 2-input AND Gate



Source :Elahi, (2018, p. 30)

The AND gate's Boolean logic is Y = A.B.

A two-input AND basic gate's truth table is as follows:

Table 5

AND Gate Truth Table

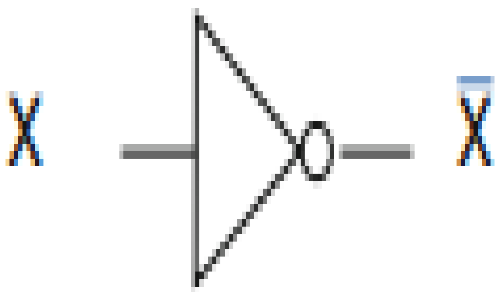
X	Y	Light
Off	Off	Off
Off	On	Off
On	Off	Off
On	On	On

c) NOT Gate

The complement operation carried out by the NOT logic reduces a 1 to 0 and a 0 to 1. The NOT X can also be represented by, which is an inverter. The NOT gate (inverter) is seen in Figure 19, and its truth table is shown in Table 5.

Figure 19

Symbol of an INVERTER Gate



Source: Elahi, (2018, p. 31)

Table 6

INVERTER Gate Truth Table

X	X'
0	1
1	0

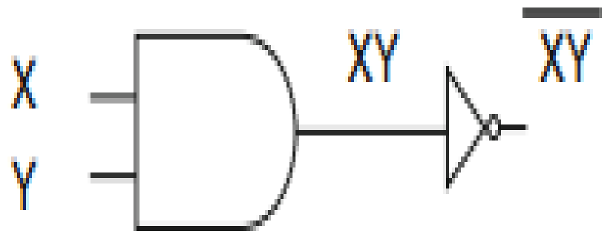
The basic logic gates NAND and NOR, which are the common building blocks of digital circuits, are created by connecting the three gates (OR, AND, and NOT) in different ways.

d) NAND Gate

This fundamental logic gate combines the AND and NOT gates.

Figure 20

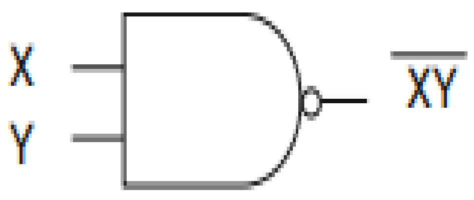
Combining AND-NOT gates creates a NAND gate



Source: Elahi, (2018, p31)

Figure 21

An NAND Gate Symbol



The NAND gate's Boolean expression is P = XY bar.

Table 5 contains a NAND gate's truth table.

Table 7

NAND Gate Truth Table

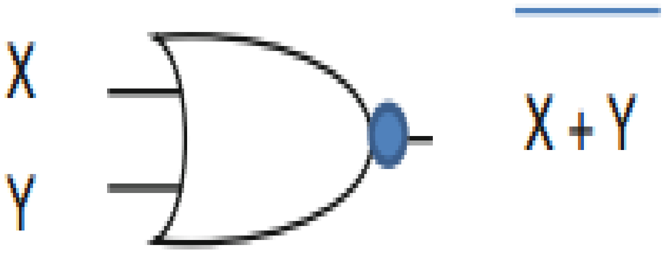
X	Y	$\overline{XY}$
0	0	1
0	1	1
1	0	1
1	1	0

e) NOR Gates

This gate combines the NOT and OR gates

Figure 22

Symbol of an NOR Gate



Source: Elahi,(2018, pg32)

NOR gate's Boolean expression is Y = A+B bar

The following is a NOR gate's truth table:

Table 8

NOR Gate Truth Table

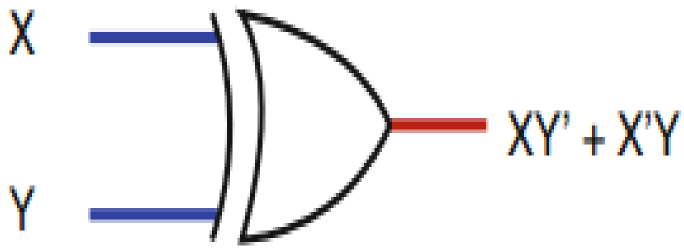
X	Y	X + Y
0	0	1
0	1	0
1	0	0
1	1	0

f) The Exclusive-OR gate

In an XOR gate, the output of a two-input XOR gate reaches state one if and only if one of the inputs.

Figure 23

XOR Gate Symbol



Source: Elahi, (2018, pg32)

The XOR gate's Boolean expression is either

$A.\bar{B} + \bar{A}.B$ or $Y = A \bigoplus B$

Table 7 displays an XOR gate's truth table.

Table 9

XOR Gate Truth Table

X	Y	$X \bigoplus Y$
0	0	0
0	1	1
1	0	1
1	1	0

When both inputs are identical, that is, both 0 and both 1, the output of an XNOR gate is in state 1.

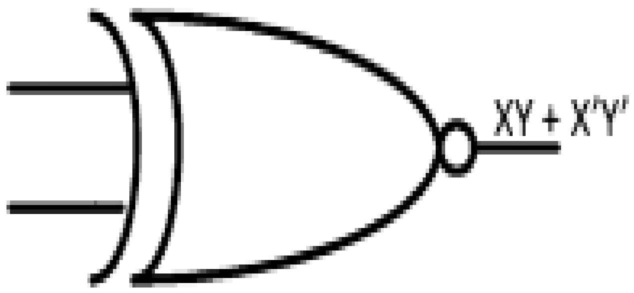
g) Exclusive-NOR Gate (XNOR Gate)

The expression for the XNOR Gate is

$$Y = (A \bar{\bigoplus} B)$$

Figure 24

Symbol for Exclusive-NOR Gate (XNOR Gate)



Source: Elahi,(2018, p. 33)

The XNOR gate's truth table is provided below;

Table 10

XNOR Gate Truth Table

X	Y	X Θ Y
0	0	1
0	1	0
1	0	0
1	1	1

a. Utilizing Logic Gates

Although there are many uses for logic gates, most of them depend on their mode of operation or the truth table associated with them. Circuits for safety thermostats, pushbutton locks, automatic irrigation systems, light-activated burglar alarms, and many other electronic devices frequently contain basic logic gates.

g) Power Source

The microcontroller-based Vehicle Overload Prevention Model can be powered by three different DC voltage sources: batteries, wall plugs, or a computer's USB port. The power level required is typically determined by the specifications of the components used to build the circuit. The actual microcontroller, along with any auxiliary gear connected to it, makes up these gadgets. Sensors or other Integrated Circuits (IC) devices might be considered peripherals. (Hailu, 2015).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The chapter describes the strategies and techniques employed to implement the creation of an Integrated Microcontroller-based model for controlling vehicle overloading. It also outlines the research techniques used in the creation, development, and application of the model. Heever (2021) defines a research technique as the procedures used to find, select, process, and analyze data related to a specific topic area.

3.2 Research Design

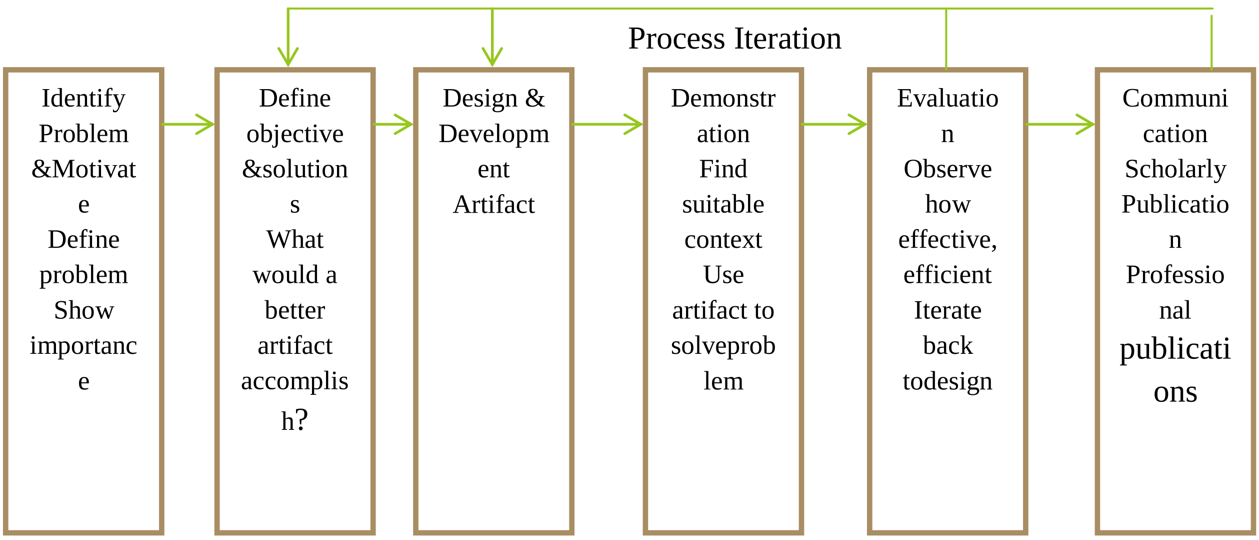
The research design adopted was a mixed methods research design. Mixed methods research offers advantages that counterbalance the limitations of both quantitative and qualitative studies.Mixed methods research is “practical” in the sense that the researcher is free to use all methods possible to address a research problem. It is also “practical” because individuals tend to solve problems using both numbers and words. In this study, there is non-numerical data, such as audio-visual material, and a description of the solution to prevent vehicle overloading, which requires a qualitative method to collect. There is also numerical data that was collected from the artifact, which requires a quantitative method for analysis.

For objective 1 of this research study, a qualitative method was applied. The researcher gathered information from audiovisual material (K24 News on the overloading of PSVs), the National Road Safety Action Plan 2021-2025, and NTSA annual reports, among other materials. The design science research (DSR) approach, frequently employed in the information systems field, was applied in this study for objectives 2 and 3. For objective 4, the model evaluation and proof of concept were used. Design Science Research (DSR) is a paradigm for problem-solving that aims to advance human knowledge by producing creative objects (vom Brocke et al., 2020). This microcontroller-based research employed the design science approach as an outcome-based information technology research technique to assist in directing the design and provide guidelines for the assessment and pre-implementation phases. This methodology differs from others used in scientific research in that it contributes new knowledge in the form of an artifact or system design (Mullarkey, 2019).

This research uses the Design Science Research (DSR) methodology to guide the creation of a microcontroller-based system designed to monitor and control vehicle overloading. DSR offers a structured, iterative approach that helps bridge the gap between theory and practical solutions. It involves six key stages—problem identification, defining objectives, design and development, demonstration, evaluation, and communication. Each of these stages plays an important role in shaping a solution that is not only technically sound but also relevant and effective in addressing the real-world challenges of enforcing vehicle weight limits.

Figure 25

DSR Process Model



Source: Vaishnavi et al., (2019)

a) **Activity 1.** The process begins with identifying and understanding the core problem—vehicle overloading—which remains a serious issue, particularly in areas where access to static weighbridges is limited and enforcement is often inconsistent. To gain a clearer picture, the research examines current solutions, including static weighbridges, weigh-in-motion systems, and other enforcement tools. While these systems serve their purpose, they come with significant drawbacks: they're often expensive, fixed in place, sensitive to environmental conditions, and in some cases, vulnerable to manipulation. Through field observations and conversations with transport officials, it becomes clear that there's a pressing need for a solution that is not only accurate and reliable but also affordable, portable, and suitable for use in a wide range of settings including remote or rural areas where traditional infrastructure may not be feasible.

b) *In Activity 2: Define the Objectives of a Solution*

With the problem clearly understood, the next step is to define what the solution needs to achieve. At this stage, the research outlines specific goals for the system design. The system should be affordable and easy to build, using modular components that can be adapted or expanded as needed. It also needs to be energy-efficient, making it suitable for locations with limited access to power. Most importantly, it must accurately measure axle loads in real time, using a microcontroller as the core processing unit. To make enforcement practical, the system should include local alert features—such as buzzers or LED indicators—and also support remote communication via GSM or IoT modules, allowing data to be monitored on-site or sent to a central authority. Finally, the design must be tamper-resistant and flexible enough to handle different types of vehicles, ensuring its usefulness in a variety of real-world scenarios.

c) *In Activity 3*— Design and Development

Once the objectives are set, the next step is to move into the design and development phase. This involves carefully selecting the right components to bring the system to life, starting with sensors such as strain gauges or load cells that can accurately measure the weight applied by each axle. These sensors are then connected to a microcontroller platform, such as an Arduino, ESP32, or STM32, which serves as the system's central processing unit. The microcontroller is programmed to read and process the sensor data, apply calibration logic, and trigger alerts whenever the measured weight exceeds predefined thresholds. A display unit can be added to show real-time weight readings directly at the site, while GSM or Wi-Fi modules enable the system to send alerts or upload data to a central server for remote monitoring. Power supply is also a key consideration at this stage; options such as battery packs or solar charging systems are explored to ensure the system can operate reliably in the field. Throughout this phase, both hardware and software come together through activities such as circuit design, coding, sensor calibration, and physical prototyping, laying the foundation for a fully functional model.

d) In Activity 4 Demonstration

With the prototype built, the next step is the demonstration phase, where the system is put to the test under controlled conditions. At this stage, reference weights or test vehicles are used to simulate real loading scenarios. The prototype is either set up on a custom test rig or integrated into a small-scale axle simulation platform to evaluate its performance under various load conditions. The primary objective is to determine if the microcontroller can reliably read and process the weight data in real-time, and whether the system’s logic—such as triggering a buzzer or sending an SMS alert when an overload is detected—functions as expected. This phase is crucial for identifying any issues early and verifying that the system behaves as intended before proceeding to more rigorous evaluations.

c) *In Activity 5* Evaluation

Next comes the evaluation phase, where the focus shifts to testing how well the system actually performs in practice. The prototype's weight readings are compared against standard reference tools, such as certified static scales or calibrated test weights, to verify its accuracy. Beyond just accuracy, other important factors are also considered, such as how quickly the system responds, how reliably it communicates alerts, how efficiently it uses power, and how easy it is for someone to use and interpret the system. This stage helps determine whether the prototype meets the technical and functional goals set earlier in the project. Where possible, feedback is also collected from likely end-users such as traffic enforcement officers or transport engineers to gain insights into how practical and scalable the system would be in real-world operations.

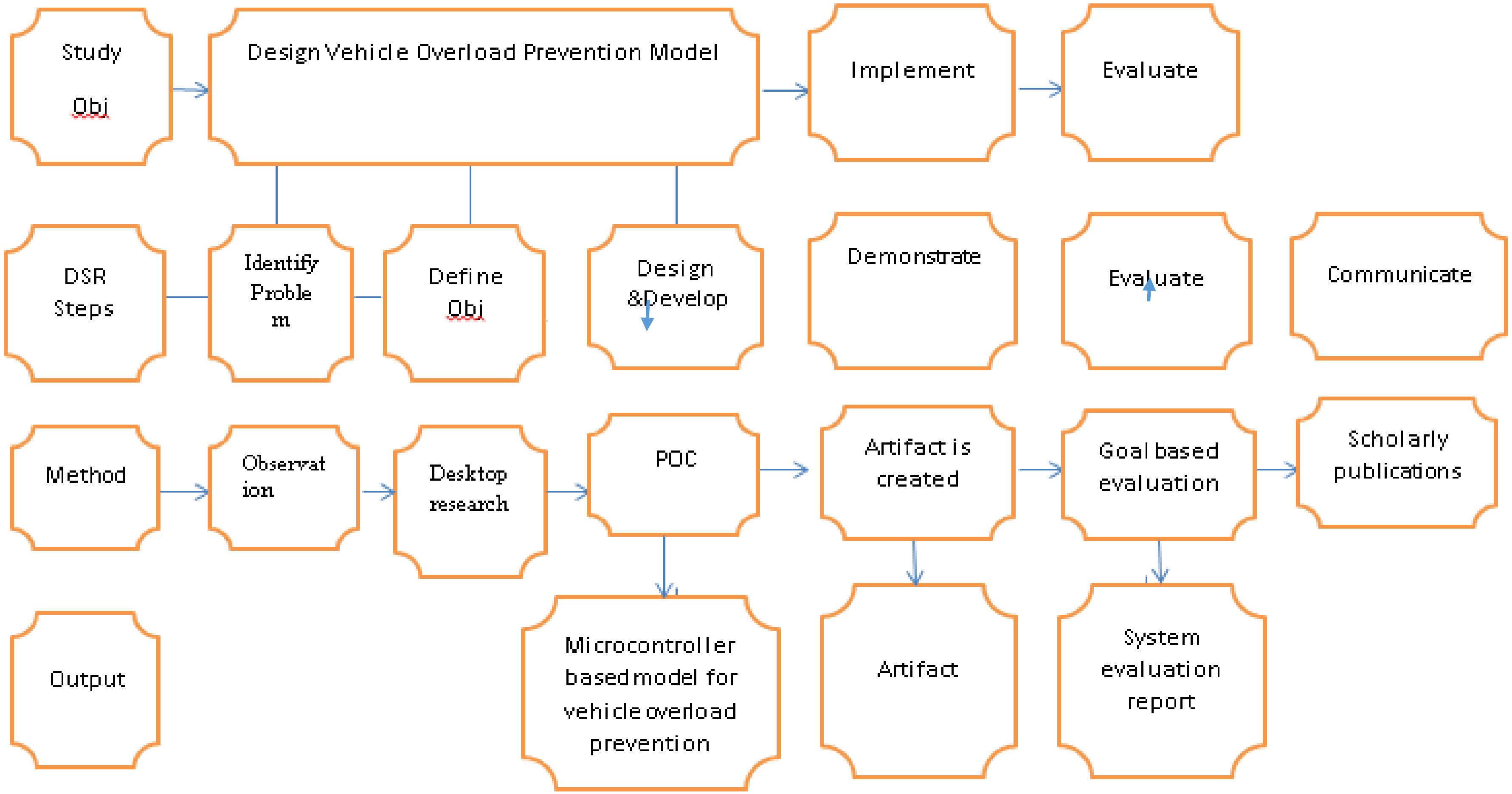
d) *Activity 6. Communication*

e) Finally, in the communication stage, the research outcomes are compiled and shared through various academic channels, including this thesis, technical reports, and potentially journal publications. These stages involve clearly documenting the entire development journey from how the system was designed and which components were chosen, to how it was calibrated, tested, and what challenges were faced along the way. The findings also include performance results and key insights that can help guide others working in the same field. Practical recommendations are provided for deploying the system, particularly in low-resource environments where traditional enforcement tools are either too costly or unavailable. Looking ahead, the study also explores areas for future improvement, such as integrating machine learning to recognize patterns in overloading behavior or expanding the system to identify different types of vehicles. This final step ensures the research contributes not only a working solution but also valuable knowledge for the wider community.

By following this structured DSR approach, the research not only results in a functional prototype of a microcontroller-based system for detecting vehicle overloading, but also offers practical insights that can inform future technological solutions aimed at enhancing road safety, optimizing freight management, and reducing infrastructure damage caused by overloaded vehicles.

Figure 26

Design Science Process for the Integrated Model for Vehicle Overload Prevention based on Microcontroller (Source: Researcher



3.3 Design of a Microcontroller-Based Model for Vehicle Overload Prevention

The design of the model was taken using the following steps:

3.3.1 Problem Identification and Motivation-Argumentative Review

To respond to the first research objective, which concerns the weaknesses of the current systems used to control vehicle overloading, the researcher proposed to use the argumentative approach to help discover and document the flaws as well as success stories in load detection and control across the globe using various forms of technology, including but not limited to microcontrollers, secondary data was reviewed via desk research. The road safety action plan (2021-2025) by the Kenyan government, relevant journals, books, and the researcher's personal experience on the road formed the basis of the argument and led to a proposal on how to mitigate the weaknesses.

3.3.2 Define the Objectives for a Solution: Desk Research

Desk research (Secondary Research) is not about collecting data, but rather reviewing the findings of earlier research to acquire more knowledge in the area of study. Based on the knowledge acquired, the researcher will be able to suggest all possible solutions to the problem being investigated. All the solutions were then analyzed individually, and the most feasible one was selected. This was done using Desk research. The most feasible solution happened to be the use of technology. This led to the design and development of a microcontroller-based model to prevent vehicle overloading.

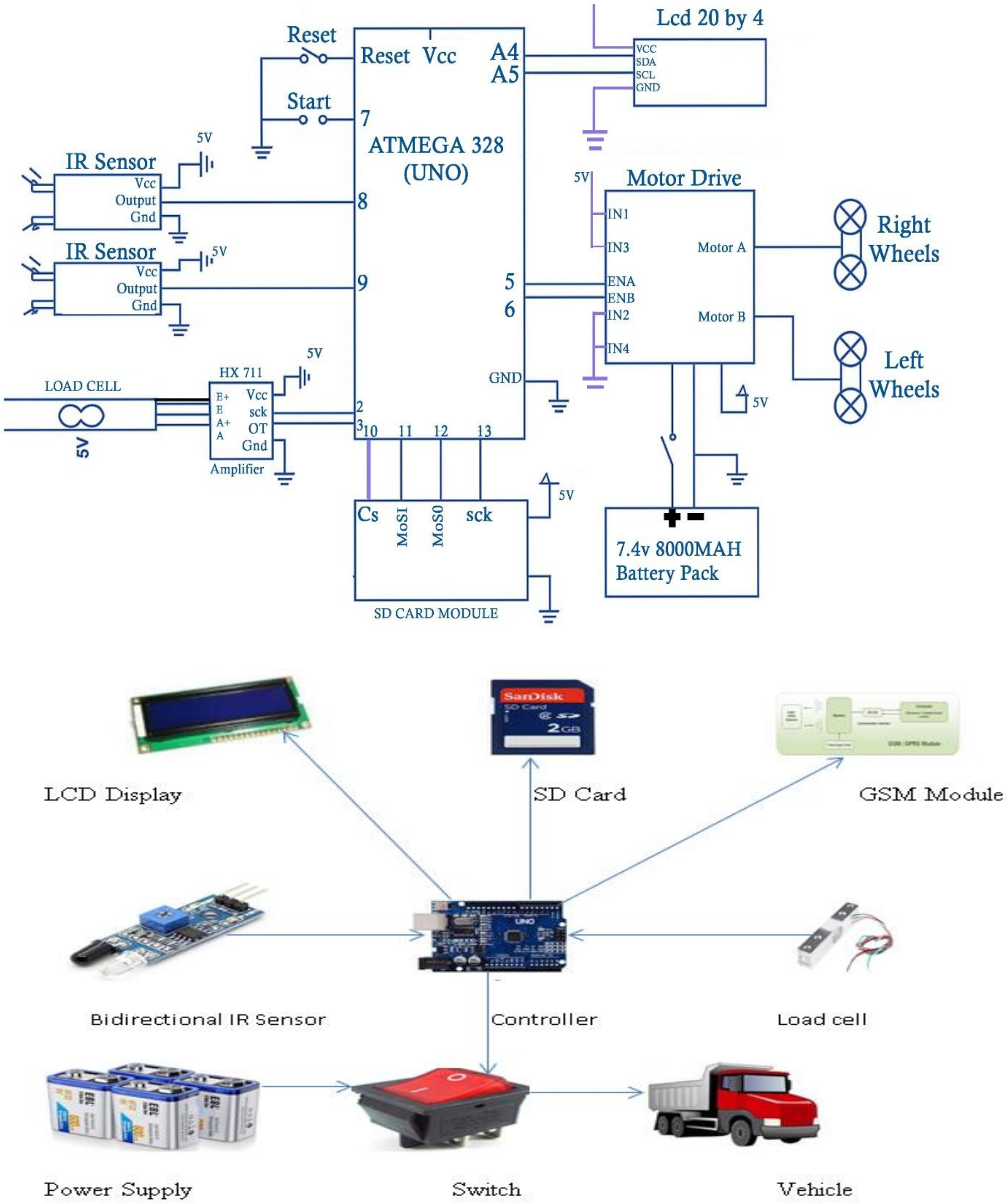
3.3.3 Model Design and Development Stage-Design Science Research Cycle

In this study, the researcher used the Design Science Research (DSR) model cycle in the design and Implementation of the model. DSR attempts to solve problems by developing artifacts (Humble et al., 2023). The model was composed of the following modules, which were later integrated to form a microcontroller-based model to prevent vehicle overloading.

1. Model Design

Figure 27

Block Diagram for the Design



Source: Authour, (2025)

The model design is guided by the logic as shown in Table 11

Table 11

Truth Table for the Design

No of passengers	weight	Output	State of Engine
0 (No of passengers not exceeded)	0 (Total weight not exceeded)	0 (Both weight and no of passengers not exceeded)	Press start switch
0 (No of passengers not exceeded)	1 (Total weight exceeded)	1 (weight exceeded but no of passengers not exceeded)	Vehicle stopped
1 (No of passengers exceeded)	0 (Total weight not exceeded)	1 (weight not exceeded but no of passengers exceeded)	Vehicle stopped
1 (No of passengers exceeded)	1 (Total weight exceeded)	1 (Both weight and no of passengers exceeded)	Vehicle stopped

i) Problem Identification and Motivation-Observation

From the information gathered and outlined in the first chapter of this study, the problem of Vehicle overloading was evident, ranging from pavement destruction to passenger discomfort and extremely serious road accidents. This phase of the DRS cycle considers the information from the literature review and the information gathered through desktop research on the minimum functional requirements for the model, as well as a report addressing the weaknesses of existing models.

ii) Suggestion for the Solution

The existing knowledge and theory base for the problem area are used to generate ideas for problem solutions (Pierce, 1931). However, these recommendations may not be sufficient to address the issue or may have significant knowledge gaps. The present models suffer from major information gaps, as emphasized in Section 2.3 of this study, and this serves as the foundation for suggesting an integrated model for vehicle overload avoidance based on a microcontroller. This model will take into account both the number of passengers and the weight of the luggage, both of which, in accordance with the Traffic Act Cap. 403, cause of overloading.

2. Model Development and Fabrication

Once the design has been accepted, implementation and verification start. The model and any extra components were constructed in accordance with the design guidelines to integrate devices without upsetting the established system or introducing weak areas. A modular design principle was followed to develop the following modules.

Step-By-Step Methodology of the Project:

"A Microcontroller-Based Model for a Real-Time Vehicle Overloading Prevention."

i) IR Motion Detector

An IR sensor is a technological innovation that produces light to detect nearby objects. The HC-SR501 PIR module sensor was used in this study. The researcher settled on this sensor because it was readily available, consumes low power (3.3 V to 15 V, which could be sourced from rechargeable dry cells), making it compatible with a wide range of microcontrollers and a detection range of 0-3meters, which is adjustable. The sensor is coupled with a lens to focus IR onto the sensor to improve detection. When a passenger moves within the range, a differential change in IR is detected. Normally, this signal is very weak and would require amplification and conditioning. A small amplifier is built into the sensor board. The output is fed into the microcontroller for comparison with a set limit. It is also displayed in the LCD.

Figure 28

Module HC-SR501PIR Sensor

HC-SR501PIR Hardware specifications:

- Model: HC-SR501, which is inexpensive and easy to use.
- Power: Requires a DC power supply, typically between 5V and 12V.
- Output: A digital signal that is LOW when no motion is detected and HIGH when motion is detected.
- Adjustable Settings:
    - Sensitivity: Controls the detection range: up to about **3-7 meters**
- Time Delay: Adjusts how long the output signal stays HIGH after motion is detected. This is crucial for counting, as a shorter delay is needed for higher traffic areas from **~ 0.3 seconds up to ~10 minutes**
- Calibration: PIR modules typically need a stable environment before use

i) Power Supply

This source will power all the modules that need power to operate. Themicrocontroller-based Vehicle Overload Prevention Model can be powered by three different DC voltage sources: batteries, wall plugs, or a computer's USB port. A set of four EBL 600mAh 9V

6F22 Li-Ion batteries was employed in this study because they are easy to use, readily available, lightweight, rechargeable, and portable.

Figure 29

Batteries EBL 600mAh 9V 6F22 Li-Ion, downloaded from the DSpace repository

A pack of four dry cells, each with a voltage of 3.7V, was used to supply the system with power. A power control unit was used to distribute power to the various modules in the correct quantity. For example, the motor requires 12V, while the microcontroller uses 5V.

iii) Display

A 20 x 4 Liquid crystal display (LCD) (i.e., 20 characters per line × 4 lines) was used to display the vehicle's status at each time. The parameters displayed were the number of passengers in the vehicle at various times, the current weight of the vehicle, whether the vehicle was overloaded or not, and whether the SD card for storage was inserted. This information was displayed on four lines with a maximum of twenty characters per line. The driver will be able to see which one is overloading the vehicle, whether it is the passengers or the weight. The choice of this type of display was guided by its thin body and space-saving design, as well as its low power consumption, which was sufficient for the artifact.

Figure 30

20 x 4 LCD Display Board

A 20 x 4 LCD will be used to display the status of the vehicle at any one time, with an 'x' indicating non-compliance and a tick indicating compliance.

20 x 4 LCD Hardware specs:

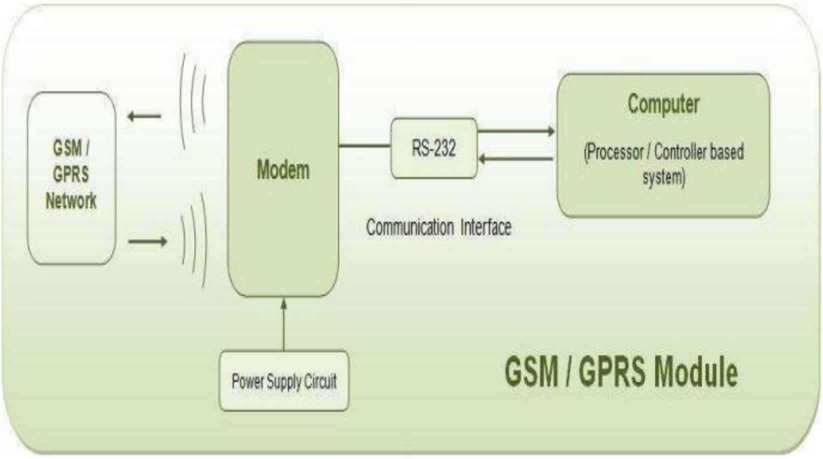
- Display format: **20 characters × 4 lines**.
- Interface: Standard Parallel (4-bit or 8-bit) interface.
- Power supply (logic): Generally,**+5 V** for logic/supply.
- Adjustable contrast and an LED backlight
- A viewing area of roughly 76mm x 25.2mm

iv) GSM Module

A GSM (Global System for Mobile Communications) modem is a specific type of modem that functions similarly to a mobile phone by accepting a SIM (Subscriber Identity Module) card and utilizing a mobile operator's subscription. When a GSM modem is connected to a computer, the computer can communicate using the GSM modem to send and receive SMS (Short Message Service) and MMS (Multimedia Messaging Service) through the mobile network. SIM800L was used in research. It is a compact GSM module (cellular modem) made by SIMCom. It enables the microcontroller to communicate over cellular (2G) networks and send SMS. Whenever an overload is detected, either in terms of passengers or luggage, the GSM module transmits a Short Text Message (SMS) to the NTSA, the Traffic Police, and the car's owner. For this study, the short message was to be sent to the researcher's SIM card number 0722337962.

Figure 31

GSM Modem



Source: Hailu (2017)

SIM800L is relatively inexpensive, supports different GSM bands, supports SMS communication mode, and has a compact size that enables integration into small device.

SIM800L Hardware specs

Communication & Security: GSM is a compact GSM module (cellular modem) made by SIMCom. It enables the microcontroller to communicate over cellular (2G) networks and send SMS.

- Network: GSM 850/900/1800/1900 2G capability
- Module dimensions: Very compact

- Supply voltage: 3.4V to 4.4V

v) Cutout

This is a switch that will be activated whenever the permitted weight or the number of passengers is exceeded, and therefore, the engine will not start.

Figure 32

Power Switch

vi) Storage

Data collected by the microcontroller can be uploaded to the cloud for analysis and tabulation. The data can be sent to the transport agencies and the investor for the necessary action to be taken. An SD (Secure Digital) card was used to store data in this model.

Figure 33

Secure Digital Card

It was selected because it is less expensive and easier to manage/erase / backup, and is more than sufficient for logging sensor data for this study.

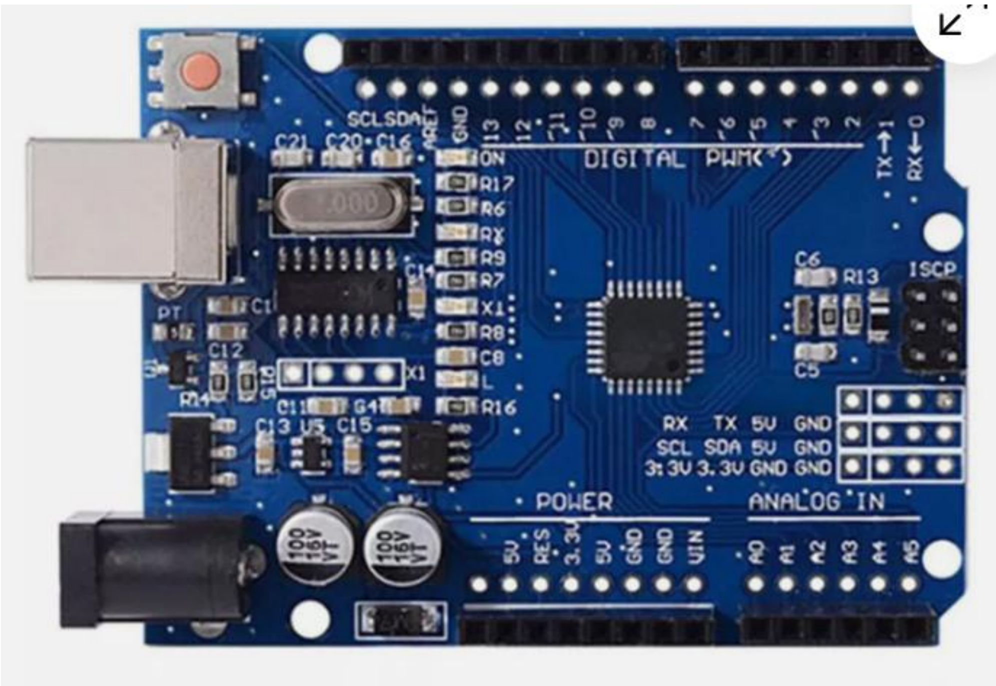
vii) Microcontroller

A microcontroller is a small computer on a single IC that integrates all the features that are found in a microprocessor. To serve various applications, it features a high concentration of on-chip facilities, including RAM, ROM, I/O ports, timers, serial ports, clock circuits, and interrupts. Numerous automatically operated gadgets, including remote controls, car engine control systems, medical equipment, power tools, office equipment, toys, and other embedded systems, all use microcontrollers. There are several types of microcontrollers on the market today. This includes the ARM (Advanced RISC Machine) Microcontroller, MSP Microcontroller (Mixed Signal Processor), AVR Microcontroller (Atmel’s RISC Processor), and the Arduino Uno's ATmega328 microcontroller.

The Arduino Uno’s ATmega328 microcontrolleris widely recognizedfor itssimplicity, affordability, versatility, and strong community support**,** making it an ideal choice for both educational and industrial applications. Its compact design, low power consumption, and ease of programming through the Arduino IDE make it highly suitable forembedded system development, prototyping, and automation projects**.** The ATmega328 operates at16 MHz**,** features 14 digital I/O pins(6 of which provide PWMoutput)**,** 6 analog input pins**,** and supports communication viaUART, SPI, and I²Cinterfaces. Its integration ofFlash memory (32 KB), SRAM (2 KB), and EEPROM (1 KB)ensures efficient data handling and program storage, providing a dependable platform for microcontroller-based projects such asvehicle overload monitoring systems(Arduino.cc**,** 2024).

Figure 34

Pin Diagram of The Arduino Uno's ATmega328 Microcontroller



*Source:*Interaction Design Institute Ivrea (IDII)

ATmega328Microcontroller Specs:

Microcontroller: The Arduino Uno's ATmega328 microcontroller has a 16 MHz clock speed, 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM. It features 14 digital input/output pins (6 with PWM), 6 analog input pins, and can supply 40 mA of DC current per I/O pin.

The microcontroller will serve as the control unit, receiving the current weight from the load cell and the current count of passengers. These two parameters will be compared with the set limits, and if exceeded, they will activate the cutout to prevent the engine from starting. Otherwise, the engine will start.

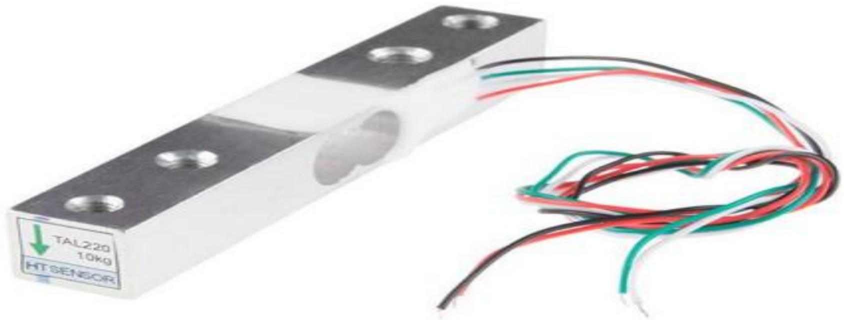
viii) Load Cell

A load cell (force sensor) is a device that converts a mechanical force, such as weight, into an electrical signal that can be measured and processed. Strain-gage-based load cells are the most widely used today. The main body of the load cell is made from metal. Strain gauges (thin metallic foil or wire in a zigzag pattern) are bonded to the surface of the elastic element at locations where strain occurs. The strain gauges are wired as part of a Wheatstone bridge (commonly 4 gauges, two in tension and two in compression) for maximum sensitivity and temperature compensation. A stable excitation voltage is applied across one diagonal of the bridge.

The output (difference voltage across the other diagonal) is zero under no load (bridge balanced). Under load, the resistances become unbalanced. The output voltage is proportional to the load. This change is typically small. Because the raw signal is small, it is amplified and filtered. ADC: HX711 was used to amplify this signal. The load cell is calibrated with known weights across its entire range to establish the relationship between the voltage output and the applied load. Corrections for non-linearity, hysteresis, repeatability, creep, zero drift, and temperature effects are often applied. Strain-gauge-based load cells offer good accuracy (with a full-scale accuracy of 0.25% or greater) and are the de facto industry standard, providing linearity, low cost, and wide availability.

Figure 35

Diagram for Load Cell



Source: Scalenet.com

A 3 kg load cell will be used to detect the total weight of the luggage and passengers, which will be compared with the tare weight as indicated by the vehicle manufacturers to prevent overloading.

Load cell specs

Sensors: Strain gauge load cells (2–3 mV/V, IP67).

Calibration & Environmental Protection

- Calibrate each load cell using certified weights at 5 points.
- Apply temperature compensation, waterproofing, and shielding.
- Schedule periodic recalibration and maintain calibration records.

Signal Processing & Data Handling

- Use low-noise amplifiers and anti-alias filters.
- Sample static loads at 10–50 SPS, dynamic/WIM at ≥1 kHz.
- Apply digital filtering (moving average/FIR) and peak detection for axle weight estimation.

ADC: HX711 24-bit Sigma–Delta with external HX711 ADC, PSoC can detect small DC signals in the range of ±20 mV, ±40 mV or ±80 mV at 10 Hz or 80 Hz sampling rate. Components consume little to no hardware resources and sparea few clocks (~0.01%).

Firmware & Software Design

- Use RTOS for task separation: sensing, processing, comms, logging.
- Include watchdogs, error logging, and OTA update support.
- Store calibration and configuration in non-volatile memory.
- C++ was used to program the hardware.

Standards & Compliance

- Align accuracy and testing with OIML R134 and ASTM E1318.
- Validate system via static and dynamic weighing tests with traceable weights and reference vehicles.

viii) DC Motors

DC motors were employed in this model. It is a device that converts electrical energy into mechanical rotational energy. The rotors and stators are the primary components of the motors. Typically, the stator includes the permanent magnet and bush assembly, while the rotors typically include the armature and commutator assembly. The windings are subjected to current flow, which creates a magnetic field. It generates torque on the rotor, causing it to rotate, which in turn turns the wheels.

The first requirements selected in the Plan phase direct the efforts of the model design experts. These experts create the model in accordance with the original specifications, taking into account any new information learned through model analysis, model audits (when updating an existing model), and discussions with transportation organizations and system users. The resulting model design definition contains specifications to enable availability, reliability, security, scalability, and performance in addition to meeting current system and technological needs. The implementation activities are built on the foundation of this design specification.

***Challenges Faced During Integration of Components*.**

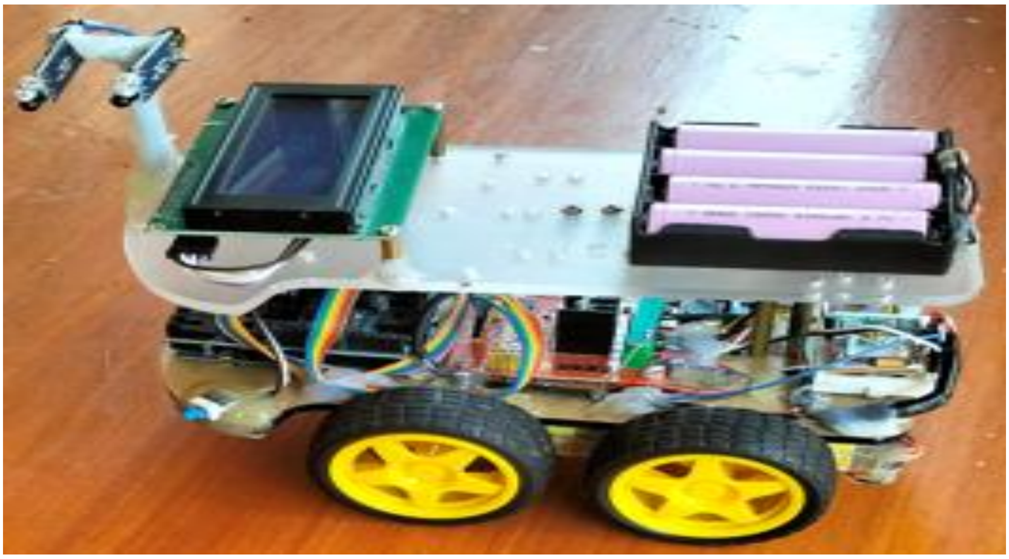
During system integration, several challenges were encountered. The load cell signals were affected by electrical noise, necessitating shielding and grounding to ensure stability. Calibration inconsistencies arose due to variations in sensor sensitivity and temperature drift, necessitating repeated calibration and compensation. Power fluctuations caused voltage drops, which were resolved through the use of a regulated power supply and filtering. Communication delays and data loss occurred during wireless transmission, which were mitigated by buffering and proper synchronization. Mechanical misalignment of load sensors reduced accuracy, necessitating precise mounting. Firmware integration posed timing and memory conflicts, which were addressed through modular coding and RTOS scheduling. Additionally, environmental factors such as temperature and humidity affected performance, while limited field testing with actual vehicle loads constrained validation.

3. Model Implementation and Evaluation

The implementation and evaluation of the model were achieved using a proof-of-concept (PoC) methodology. PoC is a valuable tool within the design science process, and it entails an organized approach used to verify the viability of an idea before spending significant resources in actual development. A prototype of a vehicle was fabricated to prove the research idea.

Figure 36

Prototype



The researcher noted that implementing the overload detection system in an actual car presents several significant legal challenges, including:

*a) **Licensing and Approval Process***

In Kenya, modifying a vehicle significantly from its original design requires approval from the National Transport and Safety Authority (NTSA). This process involves various stages, including Application submission with detailed modification plans and justifications, as well as vehicle inspections by NTSA-approved engineers. There is a need for the proposed modifications to comply with safety regulations before they are approved, and a certificate of compliance with the modifications is issued. This process is not only costly but is likely to consume more time than the typical timeframe for a master's thesis project.

b) Cost and Risks

Integrating the system into an actual car requires purchasing and installing industrial hardware, such as sensors, controllers, and displays.This can be expensive, especially considering the potential need formodifications to accommodate new components.Furthertesting the system in a real-world environment carries risks ofmalfunction, vehicle damage, and potential safety hazards.

Therefore, to settle on a prototype as opposed to a real vehicle for implementation and evaluation of the artifact, the researcher consulted with Pixels Engineering Africa, a specialist in implementing such electrical systems in vehicles. The company provided an advisory report presented in Appendix VII.

4. Model Evaluation

Evaluation is a crucial activity in the DSR process, as it indicates whether an artifact is effective or not (Herselman, 2015). The DSR process utilizes the PoC method as a tool for concurrently performing the activities of building and evaluating the artifact, thereby reflecting the progress achieved and triggering artifact revisions early in the design process.

Since vehicles are life-critical systems, the feasibility of the Overload Prevention artifact must be assessed before its actual deployment. Hence, the reason for using PoC was to implement and test the feasibility of the vehicle overload prevention concept. This was done to demonstrate that the product idea is practical and can be further developed. It also serves as an initial checkpoint that validates the basic viability of the product idea before delving into more detailed design and development stages (Kaur, 2020). Other metrics to be evaluated for the artifact are indicated in Table 13, with Table 14 providing the overall evaluation performance in terms of percentages.

These metrics include accuracy, which evaluates the correctness of the passenger counter and the weight detector, and reliability, where the system is assessed to determine whether it can stop the motor when an overload is detected. Performance and consistency were also evaluated. As per the expert opinion advisory provided by Pixel Engineering

Africa, as presented in Appendix VII. To attain the results, a purposive sampling was used with a sample size of 30. The data is shown in Table 12 below, as extracted from the SD card serial numbers 1311 to 1324.

Table 12

Data Table

S/No	Count	Mass (tare wt.)	Start switch status	Vehicle status	Count status	Mass status	Text Message
1311	0	976	0	0	✓	✓	
1312	1	1020		0	✓	✓	
1313	2	1053	0	0	✓	✓	
1314	3	1089	0	0	✓	✓	
1315	4	1127	0	0	✓	✓	
1316	5	1156	0	0	✓	✓	
1317	6	1193	0	0	✓	✓	
1318	6	1239	0	0	✓	×	1205 13:02 Sun Jan,2025
1319	6	1239	0	0	✓	×	
1320	6	1194	0	0	✓	✓	
1321	7	1194	0	0	✓	✓	
1322	8	1194	0	0	✓	✓	
1323	9	1194	0	0	×	✓	9 13:07 Sun Jan,2025
1324	10	1194	0	0	×	✓	

Table 13

Evaluation Table

Parameter	Counter	Mass Detector	Overload Communication
Performance	The counter accurately registered passenger and vehicle count from 0 to 10 with minimal delay and no false triggers.	The mass detector recorded consistent tare weight variations with clear differentiation between normal and overload states.	The system successfully generated and sent overload alerts (SMS) upon threshold exceedance.
Accuracy (%)	96.7% — Two missed detections out of 30 trials.	93.3% — Two mass readings (entries 1318, 1319) showed detection failure.	90.0% — Two messages (entries 1318, 1323) successfully sent but delayed, one missed due to signal lag.
Reliability (%)	98.0% — Stable response under repeated counting tests.	95.0% — Stable readings after calibration; minor drift under load change.	92.0% — Reliable message triggering when overload was detected, minor delay due to network.
Consistency (%)	97.0% — Maintained steady response across all iterations.	94.0% — Mass readings stable and repeatable within ±1.5% margin.	91.0% — Message alerts consistent with overload status; rare latency observed.
Feasibility (%)	100% — Easy integration with microcontroller and low-cost PIR interface.	97.0% — Compatible with load cells and ADC module, practical for local fabrication.	95.0% — SMS/GSM module practical for enforcement integration and scalable for IoT expansion.

Table 14

Overall System Evaluation

Subsystem	Average Accuracy (%)	Overall Remark
Counter	97.9%	Highly accurate, reliable, and feasible for real-time passenger counting.
Mass Detector	94.8%	Performs well under controlled conditions; requires fine calibration for full-scale deployment.
Overload Communication	92.5%	Functional and practical for automated reporting; network latency slightly affects timeliness.

Summary

Overall system mean accuracy: (97.9 + 94.8 + 92.5) / 3 = 95.1%

The system achieved a mean operational accuracy of 95.1%, demonstrating strong reliability and consistency in monitoring and controlling vehicle overloading. Minor calibration and communication refinements can further enhance performance for large-scale deployment.

The following are some of the advantages of using a prototype to prove the research idea.

a) Prototype Advantages and Scalability

While implementing the system in an actual car poses significant challenges, utilizing a well-designed prototype offers several advantages, including cost-effectiveness due to readily available components and simpler designs, significantly reducing cost compared to modifying an actual car. Prototypes operate in a controlled environment, minimizing risks associated with real-world testing.

b) Workability and Problem Solving

The proposed system addresses the critical issue of overloading in PSVs, leading to potential safety hazards, vehicle damage, and infrastructure damage. By integrating bidirectional IR sensors and load sensors, the system can detect passenger and cargo overload in PSVs, preventing unsafe conditions. The prototype demonstrates the feasibility of the system's core functionalities, providing valuable proof-of-concept for future real-world implementation.

3.4 Instrumentation

In research, instrumentation refers to the tools and methods used to collect data, encompassing everything from questionnaires and surveys to interviews and observations, ensuring data is gathered accurately and reliably. In this study, the researcher employed the Observational data collection method by utilizing a simulated model of a vehicle to vary the independent variables, namely, passenger and load, to examine their effect on engine start and stop. Observation, as the name implies, is a way of collecting data through observing. Observation, as a data collection method, can be either structured or unstructured. In structured or systematic observation, data collection is conducted using specific variables and according to a pre-defined schedule. The observational method of data collection is a straightforward approach, allowing the researcher to observe all the happenings, note them down, and form a hypothesis based on the observations.

In research, a variable is any characteristic or attribute that can vary or change, and researchers often categorize them as independent (the cause) or dependent (the effect). In this study, there are two variables: the weight of luggage in the vehicle and the number of passengers, both of which are independent variables. The dependent variable is the switching on/off of the motor, which acts as the engine, depending on whether the weight or the number is exceeded.

3.4.1 Pilot Testing

While a real-world pilot test of the microcontroller-based vehicle overloading system was initially planned, it could not be carried out due to regulatory challenges, particularly the need for approval from the National Transport and Safety Authority (NTSA). To evaluate the system’s performance, we developed a bench-top prototype and tested it using simulated load inputs, while monitoring the microcontroller's sensors. This helped us partially validate the system’s functionality.

3.4.2 Validity of the Instrument

Validity in research instruments, or measurement tools, refers to the extent to which the instrument accurately measures the concept or variable it is designed to measure. A valid instrument is crucial for obtaining meaningful and reliable results in research, as it ensures that the data collected is relevant and accurate. A known mass was used to test the validity of the load cell, and the result agreed with the expected weight. The load cell was used to measure weight. Whenever there was a weight change, it had to be detected, displayed on the dashboard, saved on the SD Card for future reference, and, in the event of excess weight detection, it was sent to the vehicle owner. For the number of passengers, the bidirectional PIR Sensors will count the passengers getting into and out of the vehicle. This number will be displayed on the dashboard, saved on the SD Card, and in the event of any attempt to exceed the capacity, the vehicle owner will be notified. This information is indicated in Table 15.

Table 15

Validity of the Instrument

Instrument/ Component	Purpose	Validation Method	Observation	Validity Conclusion
Load Cell (Mass Detector)	Measures vehicle weight and detects overloads.	Tested using a known standard mass; readings compared with actual weight.	The measured weight matched the known mass with negligible deviation (<2%).	Valid — Accurately measures vehicle load and detects overloads.
PIR Sensors (Passenger Counter)	Counts passengers entering and exiting the vehicle.	Tested using controlled entry/exit of known number of passengers.	The count displayed matched the actual number in all trials.	Valid — Accurately detects and counts passengers in both directions.
Dashboard Display & SD Card Module	Displays and stores recorded data for reference.	Verified that every change in weight or count was displayed and stored correctly.	Data recorded and retrieved matched real-time measurements.	Valid — Reliable data display and storage.
GSM Module (Communicatio n System)	Sends overload notifications to vehicle owner.	Tested by triggering overload condition and monitoring SMS alerts.	Overload alerts were sent successfully with minimal delay.	Valid — Ensures effective and timely communication of overload events.

Overall Conclusion:

All instruments were found to be valid, as they accurately measured and recorded their intended parameters with consistent and reliable performance.

3.4.2 Reliability of the Instrument

In research, instrument reliability refers to the consistency and dependability of a measurement tool, ensuring it yields similar results when repeated or used across different samples or raters. A reliable instrument consistently produces similar results under the same conditions. Reliability indicates that the instrument can be trusted to consistently measure what it intends to measure. High reliability is crucial for ensuring that research findings are valid and can be generalized. The artifact has been used in various exhibitions in different areas, and since it records and saves each occurrence, the data, when compared, totally agrees.

3.5 Data Collection Procedure

Data collection procedures in research involve planning, selecting appropriate methods, and executing the process to gather relevant information, ensuring data quality and alignment with research objectives.

To address the first research topic, which concerns the challenges of stopping overloading in vehicles, an argumentative literature review methodology was employed. Argumentative Reviews involve using selective information to support one side of an argument. (Anon, 2024) To help discover and document the flaws as well as success stories in load detection and control across the globe using various forms of technology, including but not limited to microcontrollers, secondary data was reviewed via desk research. Desk research methodology, also known as secondary research, involves collecting and analyzing information from existing sources, such as reports, articles, and databases, rather than conducting original data collection. It's a valuable tool for gaining background knowledge, supporting primary research, and informing decision-making. It is cost-effective, time-saving, and has access to a wide range of information.

Since these were secondary data, the researcher did not have to worry about the safety and monitoring of the data. The data was readily available from the internet. The relevant data was picked and used to guide the design and implementation of the model.

Data collection for model evaluation was done through a simulated model. Using a simulated model for data collection in model evaluation enables controlled testing and analysis, allowing researchers to assess a model's performance under various conditions and identify potential weaknesses or biases. Simulated data allows researchers to create specific scenarios and conditions that might be difficult or impossible to replicate in real-world data collection. Based on the evaluation results, the model can be refined and retrained using simulated data to improve its performance.

3.6 Data Analysis and Presentation

In research, effective data analysis and presentation are crucial for drawing meaningful conclusions and communicating findings clearly. Data analysis involves processing and interpreting data to identify patterns and relationships, while presentation utilizes visuals, such as charts and tables, to make complex information more accessible.

A descriptive data analysis method was used to analyze the collected data.Descriptive data analysis offers several advantages, including providing a clear, accessible summary of data, revealing trends and patterns, and facilitating informed decision-making by presenting information in a readily understandable format. In this study, the data were presented in a tabular form.

3.7 Ethical Considerations

A number of ethical guidelines were followed when collecting requirements and testing the model. To develop a model, the researcher will seek data that supports the goals of these studies. The ethical consideration will align with the guidelines set forth by regulatory bodies. An introductory letter from Kabarak University's Institute of Postgraduate 34 and Research and a permit from the National Commission for Science Innovation and Technology (NACOSTI) will be used to do this. Any information gathered for this study from either source will be kept private and confidential.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1 Introduction

This chapter presents the findings, interpretations, and discussion in accordance with the objectives outlined in Section 1.3 of this research study.

4.2 Weaknesses in the Current Systems for Preventing Vehicle Overloading

This section presents the results for Objective One of this research study, which aimed to investigate why overloading of vehicles has become a perennial problem despite all the strict measures taken to tighten the management of the transport sector and control vehicle overloading. These have been in place for the last few years, but overloaded vehicles are still operating on many roads. This was done at stage one of the design science research methodology, where both primary and secondary data were collected. Primary data was obtained through observation.

Secondary data were collected through an extensive desk review of laws, policies, regulations governing the transport sector, and other relevant publications. Among these was the Constitution of Kenya; The Public Officers Ethics Act, No. 4 of 2003; Kenya Bribery Act, 2016; Anti-Corruption and Economics Crimes Act, 20031; National Police Service Act; National Police Service Commission Act; The Kenya Traffic Act (Cap 403 Laws of Kenya); Transport Licensing Act (Cap 404 Laws of Kenya); and the NTSA regulations and fines for minor offences among others.

4.2.1 What the Researcher Observed

The study highlighted weaknesses in the systems, procedures, and policies related to the enforcement of traffic laws. Table 17, presented below, summarizes the main areas prone to misuse, leading to non-compliance with traffic laws.

Table 16

Results for Objective 1

Issues	Observations
	Ownership of Public Service Vehicles by Police Officers
Regulatory Restriction	Regulation 40, Chapter 20 of the Force Standing Orders bars most officers from owning or operating PSVs without consent from the Commissioner of Police.
Unauthorized Ownership	Many officers are involved in the PSV sector without approval, violating standing orders.
Conflict of Interest	Officers often own or control PSVs within their jurisdiction, affecting impartial law enforcement.
Uneven Law Enforcement	Traffic laws are selectively applied, especially when violations involve police-owned vehicles.
Protection Fee Arrangements	PSV operators reportedly pay monthly protection fees to police in exchange for immunity from enforcement.
	Virtual Weigh Bridge
Technology Description	Weigh-In-Motion (WIM) allows weighing vehicles without disrupting traffic, using sensors and video with OCR cameras.
Advantages	- Continuous traffic flow during weighing. - Reduces delays compared to static weighing.
Limitations	- Not real-time (data processed later). - Only serves heavy commercial vehicles (7 tons+). - Small vehicles not monitored. - Maintenance difficulties as sensors are embedded in roads. - Static weighing causes congestion and allows evasion.
	Corruption
Prevalence	-Corruption in the traffic department is a major national concern.
Examples	- Citizen TV (Jan 28, 2017): EACC arrested four traffic officers for bribery. - Bribes used to release seized vehicles from police custody.
Impact	- Weak enforcement of traffic laws. - Public mistrust and normalization of corruption.
	Passengers
Public Awareness	Most respondents disagreed that NPS traffic division conducts road safety sensitization.
Media Role	- No dedicated programs on traffic law awareness. - The media focuses on exposing corruption but lacks advocacy for prosecution.
Civil Organizations	-Few or no programs for motorists' rights or anti-corruption advocacy. - Weak civic engagement in traffic governance.
Overall Effect	-Public ignorance and complacency are exploited by matatu

	owners and police. - Passengers often support lawbreaking drivers. - Police integrity is compromised due to bribery.
	Traffic Police
Performance Ranking (2017)	Kenya’s police service ranked 3rd worst globally; Botswana and Rwanda were Africa’s top performers.
Challenges	- Lack of adequate enforcement equipment (e.g., patrol cars, weight sensors, alco-meters). - Officers often rely on public transport vehicles during operations, encouraging bribery. - Opportunities for corruption and negotiation with motorists are widespread.
	Route Allocation
Policy	PSVs are assigned specific routes for efficiency.
Issue	- Drivers operate outside designated routes, preferring lucrative ones. - Police and local authorities fail to enforce compliance effectively.
	Suspension of Vehicles
Enforcement Authority	Transport Licensing Board (TLB) and police.
Weakness	- No mechanism to ensure suspended vehicles remain off the road. - Police are informed of suspended vehicles but enforcement is poor. - Suspended vehicles continue operating illegally.
	Matatu SACCOs
Structure	Matatus operate under SACCOs; boda-boda riders have informal groups; taxi drivers and truck drivers lack umbrella organizations.
Gap Identified	Lack of unified and functional umbrella bodies; existing ones are briefcase mechanisms addressing individual interests.
Challenges	-Poor managerial skills leading to frequent splits. - Infiltration by cartels. - Weak enforcement—drivers and conductors carry excess passengers and luggage freely.

4.2.2 Suggestions for the Solutions

After exposing the weaknesses in the current systems for controlling vehicle overloading, several proposals for solutionss were suggested, as highlighted in Table 17.

It is from these proposals that the researcher picked the best. Use appropriate equipment to conduct traffic checks scientifically with minimal human intervention.

Table 17

Suggestions for Solutions

Proposed Solutions	Purpose
Enforce the provisions in the force standing orders	Ensure compliance among police officers owning PSVs.
Develop appropriate instruments for declaration of interests by officers	Enhance transparency and accountability.
Take action against police officers allowing suspended vehicles to operate	Strengthen enforcement of suspensions.
Revoke licenses for both vehicle and driver	Deter repeat violations.
Enforce conformity on route allocation	Maintain order and efficiency in public transport.
Intensify inspections to enhance TLB compliance	Ensure continuous adherence to licensing laws.
Intensify public awareness and seek public support	Improve citizen cooperation in traffic law enforcement.
Prioritize acquisition of modern enforcement equipment	Minimize human interaction and corruption in enforcement.
Best Suggestion Chosen	Use appropriate equipment to conduct traffic checks scientifically with minimal human intervention.

4.3 Design of the Vehicle Overloading Prevention Model

This section presents the results of objective two of the study. This was achieved using the design science research process methodology. This sets out the design of the microcontroller-based vehicle overloading prevention model, which follows the design science research approach and methodology, to help guide the conduct and suitability of the final product.

4.3.1 Design Recommendations Towards Implementing the Integrated Model for Vehicle Overload Prevention Based on Microcontroller

The observations as discussed in objective 1 above, lead to the suggestion of the following design recommendations that provide a solution to the challenges identified above:

a) There isa need to develop a scientific solution to prevent vehicle overloading. This differs from current systems, which are mainly manual and therefore prone to manipulation.

b) There is a need for a provision of an in-built passenger counter to prevent passengers from overloading. The current systems count the number of passengers by the number of seats, with no means of ensuring compliance.

c) There is a need for the provision of an in-built weight sensor to prevent luggage overloading. Vehicles do not have a means of ascertaining the weight. The only means is the weigh bridges, and these are designed for heavy commercial vehicles.

4.3.2 Model Design

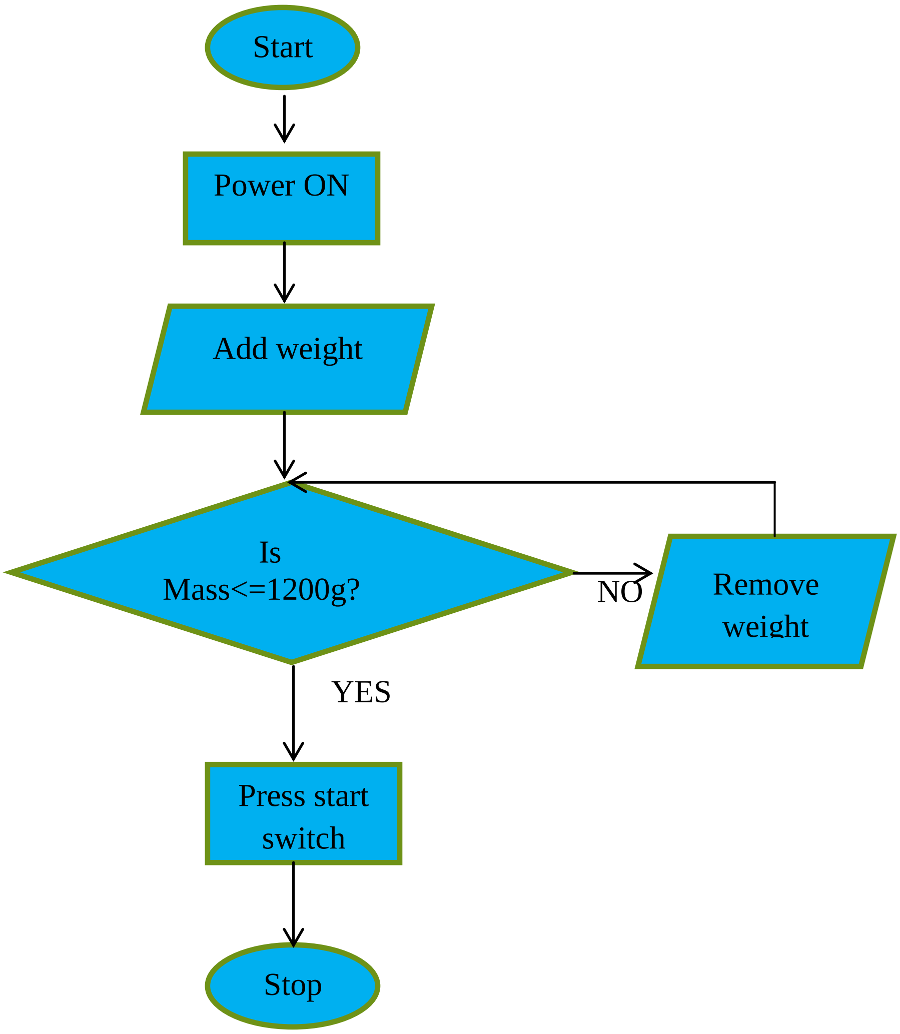
This section presents the model design and the various components used in the design, along with their functions.

a) Load Cell.

A 3 kg strain gauge-based load cell was used to measure the weight of the luggage and passengers. However, for the purpose of this study, the tare weight was set to 1.2 kg, beyond which the vehicle would not start. The current weight of the vehicle will be displayed on the 20x4 LCD Display, and if the weight exceeds the limit, it will be marked with an 'x'. This method of load detection is scientific and proactive, unlike the current systems, which are reactive and manual. It is also built in, requiring no human intervention, as opposed to the VWS, which requires human intervention for monitoring.

Figure 37

The Overweight Flow Chart

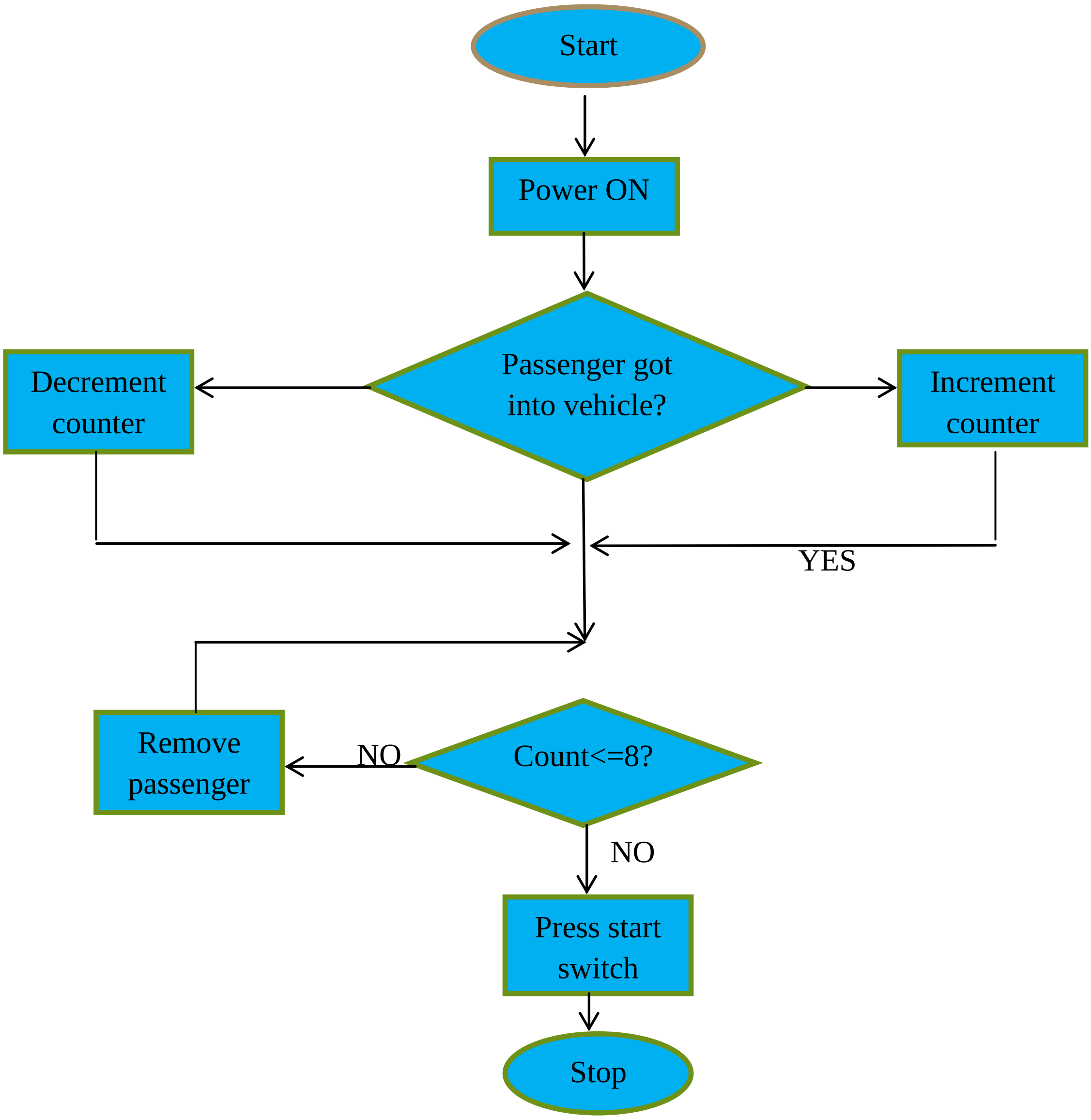


b) ***Bidirectional Counter***

For the detection of the passenger's motion, IR was used to count those getting into and those getting out of the vehicle. If a passenger gets into the vehicle, the counter is incremented; when the passenger gets out, it is decremented. This is displayed in the 20x4 LCD display and marked with a tick or an x, depending on whether the capacity has been exceeded or not. For the purpose of this study, the maximum count was fixed at 8 passengers. PIR sensors are used in this research for counting passengers. Other systems discussed in the literature use cameras that are expensive and suffer from environmental factors, such as poor lighting at night and during the rainy season.

Figure 38

The Bidirectional Counter Flow Chart



c) GSM Module

The SIM 800L was used to send a message to the vehicle's owner in case there were attempts to exceed the tare weight or the allowable number of passengers. The communication goes directly to the relevant people, rather than to a control room, as is the case in VWS. In this study, the overloaded vehicle is stopped instantly. In contrast, during the VWS, the information is first analyzed before a decision is made.

c) SD Card

This was for storing the data collected during the vehicle's working period. The information stored includes the number of passengers, the weight, and the status of the engine at any given time. This is for future reference in the event of a legal dispute. Current systems lack the means to store data, making it difficult to stand in a court of law. The only available record is the occurrence book (OB), where the offender is booked.

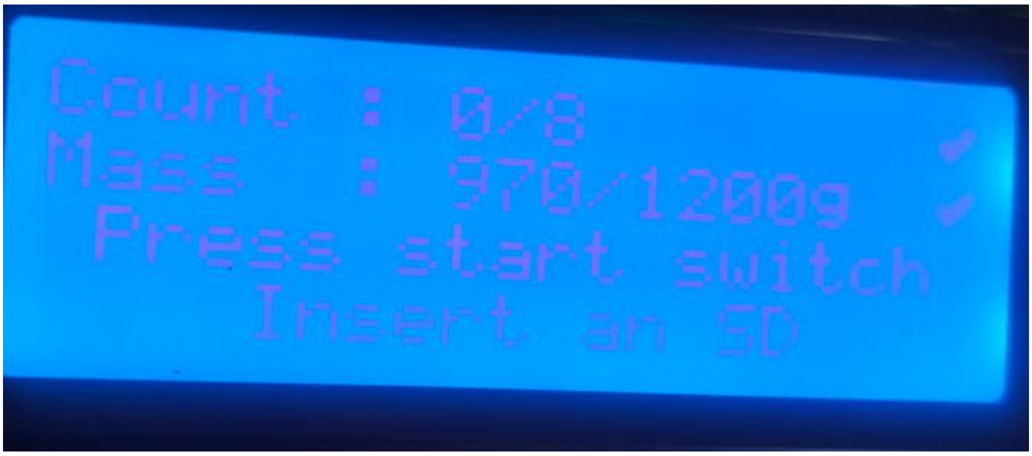
d) LCD Display 20x4

The following information was being displayed on the 20x4 LCD Display.

a) When unloaded

Figure 39

Display of an Unloaded Vehicle with no Storage Device



i) Count: 0/8 (Displaying zero passengers against the maximum number, which is 8 passengers)

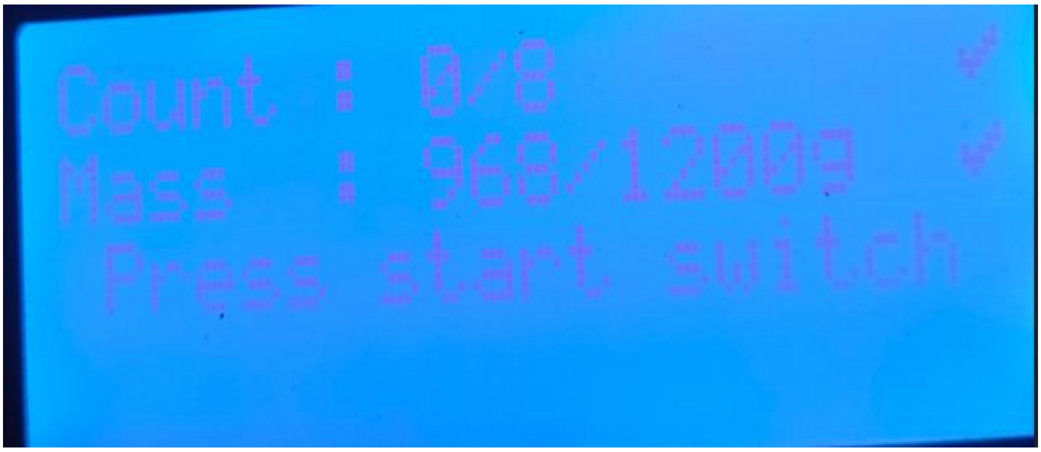
ii) Mass: 967/1200g (Weight of unloaded vehicle against the maximum weight)

iii) Press the start switch (Press start switch if the vehicle is correctly loaded)

iv) Insert SD Card (Reminds you to insert a storage device if not inserted)

Figure 40

Display of Unloaded Vehicle with Storage Device in Place



Once the storage device is inserted, the “Insert an SD” message will disappear, and any activity that takes place will be recorded.

b) When correctly loaded (1passenger and 1033g)

Figure 41

Display of a Correctly Loaded Vehicle

c) When loaded with excess weight and the correct number of passengers

Figure 42

Display of a Vehicle Loaded with Excess Weight

d) When loaded with excess passengers and the correct weight

Figure 43

Display of a Loaded Vehicle with Excess Passengers

e)When loaded with excess weight and excess passengers

Figure 44

Display of a Loaded Vehicle with Excess Passengers and Weight

e) Control Unit

It controls the whole system. The control unit was used to read data from the sensors, compare the weight and number of passengers against the set limit. If the set limit is exceeded, the control unit will deactivate the engine. The same information is also displayed on the dashboard, indicating the vehicle's current status. The driver will take an appropriate action, but the engine will not start until the excess weight or passenger is removed. An Arduino Uno board was used for this study. The currently available automatic vehicles have not yet automated passenger counting and weight detection.

f) Engine

The L298N motor drive was used to act as the engine of the vehicle. When everything is normal, the motor will start and turn the wheel. Four motors are used, one for each wheel.

4.3.3 Model Development and Implementation

This section demonstrates the attainment of research objective three of the study, which required the researcher to develop and implement a model.

4.3.4 Development and Implementation of Counter Module

This module was used to count passengers and confirm whether they were entering or exiting, updating the counter accordingly. If it was an entry, the counter was incremented; if it was an exit, the counter was decremented. The following code was used to implement this logic.

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>

#include <SD.h>

#include <SPI.h>

#define ENA 5

#define ENB 6

#define SCK 2

#define DT 3

#define switchIgnite 7

#define sensorA 8

#define sensorB 9

int8_t countr = 0;

int8_t prevCountr = 0;

int8_t maximmCountr = 8;
```

4.3.5 Development and Implementation of the Weight Sensor Module

As observed in Objective 1, passengers always carry some luggage with them whenever they travel. Sometimes the driver would even opt to carry luggage on passengers' seats. Therefore, it was necessary to ensure that the gross weight of the vehicle was not exceeded, regardless of what was on board. This was achieved by using the following code.

```
int mass;
int prevMass = 0;
float maximumWeight = 1200.0;
uint8_t motrSped = 125;
int cs = 10;
File myFile;
unsigned long waitTime = 58880;
unsigned long currentTime = 0;
unsigned long igniteTime = 0;
unsigned long saveTime = 0;
boolean sdstate = false;
boolean sdUpdate = false;
boolean sdFrst = true;
boolean countrExceed;
boolean weightExceed;
boolean runMot = false;
boolean sndMas = false;
boolean sndCnt = false;
float SCALE = 231.f; // used to return weight in grams, kg
byte GAIN = 1; // amplification factor channel A, gain factor 128
```

4.3.6 GSM Module

This module was used to send a text message to the vehicle owner whenever there were attempts to overload the vehicle, either in terms of passengers or luggage. In this research study, messages were sent to 0722337962, regardless of the network. Other recipients, such as the NTSA, the Traffic department, and Matatu Sacco, can also be added to the list of recipients. An overload in terms of count was symbolized by the digit 9. The moment count 9 is recorded, an alert with digit 9 is sent to the owner; however, the actual count is recorded on the SD card. This was enabled by using the code below.

```
void sendMess(String txtMsg) {
  Serial.println("AT+CMGF=1");
  delay(80);
  Serial.println("AT+CMGS=\"+254722337962\"");
  delay(80);
  Serial.print(txtMsg);
  delay(80);
  Serial.write(26);
}
```

The following text messages were received on various dates during periods of overload.

4.3.7 Storage

An SD Card 2.0 GB was used to store data for further analysis and future reference. The following table (Table 18) is a sample of data retrieved from the memory card.

Table 18

Data from the SD Card

Count	Mass	Start Switch	Vehicle Status
0	975	0	0
0	965	0	0
0	988	0	0
0	986	0	0
0	988	0	0
0	1014	1	1
0	984	0	0
0	988	0	0
9	1000	0	0
0	986	0	0
0	997	0	0
9	1108	0	0
0	994	0	0
10	996	0	0
10	996	0	0
0	988	1	1
0	722	1	1
0	49	1	1
0	997	0	0
0	954	0	0
0	46	1	1
0	963	1	1
0	983	1	1
0	988	0	0
0	990	0	0
1	991	0	0
1	991	0	0
0	581	1	1
0	671	0	0
0	988	0	0
0	970	0	0
0	993	1	1
0	993	0	0
8	989	0	0
3	987	0	0
0	988	1	1
0	991	0	0
9	927	1	0
9	982	1	0
0	992	1	1
9	841	1	0
0	971	0	0
0	955	0	0

For the start switch, 0 means the switch is OFF and 1 means the switch is ON. For the vehicle status, 0 means the vehicle is stopped, and 1 means the vehicle is running.

4.4 Model Evaluation

This segment outlines the findings from testing and assessing the model to evaluate its success. The assessment focused on whether the model fulfilled its intended objectives, using Demonstrations. Demonstration refers to the process of conducting research, developing new technologies, and demonstrating their feasibility in order to advance innovation and address societal challenges.The following metrics were used to evaluate the artifact: Feasibility, Accuracy, Reliability, Performance, and Consistency, and were carried out by Pixel Engineering Africa Limited. The sample size was 30, and the evaluation results are shown in Table 21.

4.4.1 Test Case 1. Counter

The model's performance was quantitatively evaluated based on its passenger countingaccuracyand directional detection efficiency. Specifically, the system was tested for its ability to increment and decrement counts corresponding to passenger entry and exit movements. During controlled trials, the counter successfully recorded passenger counts ranging from 0 to 30 with 100% accuracy across 30 consecutive test iterations. No false triggers or missed detections were observed, indicating high consistency (100%) and reliability (error rate = 0%) in directional passenger counting performance.

Table 19

Counter (Data extracted from SD serial number 1215 to 1244)

S/No	Count	Mass(tare wt)	Start witch status	Vehicle status	Count status	Mass status
1215	0	970	0	0	✓	✓
1216	0	970	0	0	✓	✓
1217	1	970	0	0	✓	✓
1218	1	970	0	0	✓	✓
1219	2	970	0	0	✓	✓
1220	2	970	0	0	✓	✓
1221	3	970	0	0	✓	✓
1222	3	970	0	0	✓	✓
1223	4	970	0	0	✓	✓
1224	4	970	0	0	✓	✓
1225	5	970	0	0	✓	✓
1226	5	970	0	0	✓	✓
1227	6	970	0	0	✓	✓
1228	6	970	0	0	✓	✓
1229	7	970	0	0	✓	✓
1230	7	970	0	0	✓	✓
1231	8	970	0	0	✓	✓
1232	8	970	0	0	✓	✓
1233	9	970	0	0	×	✓
1234	9	970	0	0	×	✓
1235	9	970	0	0	×	✓
1236	10	970	0	0	×	✓
1337	11	970	0	0	×	✓
1238	11	970	0	0	×	✓
1239	10	970	0	0	×	✓
1240	10	970	0	0	×	✓
1241	9	970	0	0	×	✓
1242	9	970	0	0	×	✓
1243	9	970	0	0	×	✓
1244	8	970	0	0	✓	✓

4.4.2 Test Case 2 Mass Detection

The mass detection unit was subjected to a series of tests under controlled load conditions. The system produced the readings as indicated in column3 of Table 20. A statistical analysis was performed to evaluate the sensor's performance.The results revealed a mean value of approximately1110.88**,** with astandard deviation of 90.7and arange of 235 units**.** The most frequently recorded value was1161**,** which appeared three times, indicating consistent sensor output under similar load conditions. However, lowervalues, such as 974 and 1022, indicate some level of variability, which may be attributed to environmental factors, sensor calibration drift, or inconsistencies in load distribution.

Table 20

Mass Detection (Data Extracted from SD Serial Numbers 1251 to 1257)

S/No	Count	Mass(tare wt)	Start witch status	Vehicle status	Count status	Mass status
1251	8	974	0	0	✓	✓
1252	8	1161	0	0	✓	✓
1253	8	1161	0	0	✓	✓
1554	8	1161	0	0	✓	✓
1255	8	1209	0	0	✓	×
1256	8	1022	0	0	✓	✓
1257	8	974	0	0	✓	✓
1286	9	1206	0	0	×	×

4.4.3 Overload Reporting

During the testing phase, the microcontroller-based system was set to flag an overload condition whenever the number of detected passengers exceeded 8 and the recorded mass went above 1200grams. Over the course of the observation period, the system successfully generated eleven overload alerts. These events, along with their respective dates, times, and measurements, are summarized below. These are messages retrieved from the phone number (0722337962). For passenger overloading events, the system encoded the alert using a fixed identifier value of **9**, regardless of the number of excess passengers. In contrast, for luggage overloading, the system transmitted the **e**xact excess mass recorded by the load cell. The overload reporting column in Table 21 indicates that the message was only sent when the overload was detected.

Count: 9, Mass: 1207 Wednesday, Oct 02, 2025 08:29

Count: 9. Mass: 1263 Friday, April 11, 2025, 15:12

Count: 9. Mass: 1205 Sunday, Jan 5, 2025, 13:02

Count: 9, Mass: 1201 Friday Aug 23, 2024 10:16

Count: 9 Mass: 1233 Thursday Aug 22, 2024 16:35

Count: 9 Mass: 1243 Thursday Aug 22, 2024 14:50

Count: 9 Mass: 1274 Thursday Aug 22, 2024 11:11

Count: 9 Mass: 1274 Wednesday Aug 21, 2024 12:45

Count: 9 Mass: 1278 Tuesday Aug 20, 2024 11:55

Count: 9 Mass: 1275 Sunday Jun 23, 2024 09:59

Mass: 1307 Friday June 21,2024 20:56

Table 21

Data for Integrated Model

S/No	Count	Mass (tare wt.)	Start switch status	Vehicle status	Count status	Mass status	Overload reporting
1311	0	976	0	0	✓	✓	
1312	1	1020		0	✓	✓	
1313	2	1053	0	0	✓	✓	
1314	3	1089	0	0	✓	✓	
1315	4	1127	0	0	✓	✓	
1316	5	1156	0	0	✓	✓	
1317	6	1193	0	0	✓	✓	
1318	6	1239	0	0	✓	×	1205 13:02 Sun Jan,2025
1319	6	1239	0	0	✓	×	
1320	6	1194	0	0	✓	✓	
1321	7	1194	0	0	✓	✓	
1322	8	1194	0	0	✓	✓	
1323	9	1194	0	0	×	✓	9 13:07 Sun Jan,2025
1324	10	1194	0	0	×	✓	

4.4.4 Control Unit

The Arduino Uno microcontroller effectively met the needs of the vehicle overload detection system by reliably handling real-time data processing, integrating with sensors, and logging events. Its balance of sufficient processing power, easy-to-use input/output pins, and straightforward programming makes it a great fit for developing prototypes and small to medium-sized applications. However, to improve the system’s stability—especially for longer-term use or when connecting more sensors—some minor updates to the firmware and better management of system resources would be beneficialto enforce overload prevention.

The control unit was programmed to inhibit vehicle operation by either disabling power to the motor during motion or preventing ignition at startup when an overload condition was detected. The system's response status under overload conditions is illustrated in the figure below. Performance evaluation focused on three key metrics: accuracy (correct identification of overload events), consistency (repeatable control response across multiple trials), and operational effectiveness (successful interruption of motor function upon overload detection). These parameters were assessed across multiple test scenarios to determine the system’s reliability in real-world conditions.

Figure 45

Display when Overload was Detected

4.4.5 Display Unit

This test case evaluated the effectiveness, accuracy, consistency, and performance of the system in displaying the vehicle's status at any given moment on the vehicle's dashboard. This would help the driver manage the vehicle. The various display figures in this chapter provide clear evidence of the system's capability to display the vehicle's status as different parameters change, indicating the appropriate action to take in each case.

4.4.6 Storage

The data, as shown in Table 18, was retrieved from the SD card used to store all the vehicle's activities. This demonstrated the system's capability in terms of accuracy, reliability, and performance in storing data for future reference.

4.5 Conclusion

The previous chapter addressed the obstacles and designs of a Comprehensive Model Aimed at Preventing Vehicle Overloading Using a Microcontroller. Additionally, this chapter examined the implementation of the microcontroller-driven model to avert vehicle overloading. Furthermore, the chapter evaluated the effectiveness, reliability, accuracy, performance, and consistency of the model in preventing vehicle overloading.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter contains a summary, conclusion, and recommendations of the research study on the integrated vehicle overload prevention model's design, development, and evaluation. It also offers additional research topics.

5.2 Summary of the Major Findings

This section of the research report presents the summarized findings as per each of the research-specific objectives

5.2.1 Research Objective 1: To Investigate the Weaknesses in the Current Systems for Preventing Vehicle Overloading

Research Question 1: What are the weaknesses in the current systems for preventing vehicle overloading in Kenya?

From the analysis of the data collected in the research, various weaknesses of the current systems for vehicle overload prevention were identified. A desktop literature review was employed to gather secondary data, while observation was used to gather primary data. The traffic police department and the National Transport and Safety Authority were keenly studied, as these two departments are mandated with enforcing traffic laws and ensuring safety on Kenyan roads. The primary objective of the traffic department is to ensure compliance with traffic laws. Inadequate resources and human capacity hinder this enforcement. Kenya lacks sufficient police officers to deploy on every road in the country. Therefore, most vehicles travel on unmanned roads where the vehicle crew is at liberty to do as they wish. Even when police officers are on the roads, they cannot be present 24/7 due to harsh weather conditions and human nature; hence, there will come a time when these roads are unmanned. Similarly, even on roads manned by policemen, they lack the necessary equipment, such as speed guns, alcohol breathalyzers, and, most importantly, weighing machines, to ensure each vehicle carries its capacity according to the manufacturer's specifications and the laws. This results in erroneous compliance.

5.2.2 Research Objective 2: Design of a Vehicle Overload Prevention Model Based on a Microcontroller

Research Question 2:What is a suitable design based on a Microcontroller to prevent vehicle overloading in Kenya?

Regarding objective 2, the researcher developed an integrated model to prevent vehicle overloading. Other models discussed in this study, such as the virtual weighbridge, control only weight or only the passengers, or both at the same time. Several solutions were suggested in objective 1 but the researcher picked on the best solution. This solution proposes the use of technology to prevent vehicle overloading, eliminating the need for human intervention. The application of technological solutions, such as weight sensors, IR motion detectors, load optimization software, and load monitoring systems, provided real-time data on cargo weight, distribution, and vehicle stability.

The real-time data obtained from these instruments facilitated decision-making and the early detection of potential overloading scenarios. Deployment of the integrated microcontroller-based model ensures uniformity and compliance with the traffic rules and the manufacturer's recommended weight. This is because the developed model takes into account both the number of passengers and the permissible weight. The developed model ensures that either the number of passengers or the permissible weight, or both, are not exceeded. If either or both are exceeded, then the cut-out will be activated. This is proactive, unlike the current reactive systems. This will reduce the number of road accidents and their associated negative impacts.

5.2.3 Research Objective 3: To Implement a Micro-Controller-Based Model to Prevent Vehicle Overloading

Research Question 3:How can a model based on a microcontroller be implemented to prevent vehicle overloading in Kenya?

The implementation of the integrated model to prevent vehicle overloading followed the design discussed in the design phase of this research study. In order to produce a workable model, this involved establishing the development platform and implementing the design. The implementation was modular, and the numerous completed parts were integrated to make the final model. The model design served as the basis for the implementation of the following modules.

LCD Display 20x4 - Enables vehicle users to view the vehicle's status and take the necessary action. This was placed in a location with clear visibility.

Bidirectional Counter - It was used to count passengers entering the vehicle and those exiting, and update the counter accordingly.

3kg Load cell- To detect and amplify weight

Micro SD Card-For data storage

Control Unit –Controls all the functions of the system

Motor Drive L298N-Acted as the engine

Motors- Used as the shaft for rotating the wheels when the engine is ON.

Power-For powering the system

The end result was a prototype as shown in Figure 36.

5.2.4 Research Objective 4:To validate the Microcontroller-Based System to prevent Overloading in Vehicles

Research Question 4: How can the implemented system to prevent vehicle overloading be validated?

To make sure the model's needs and specifications were fulfilled, it was evaluated against the functional requirements and specifications. The model was evaluated using the proof-of-concept evaluation technique to determine if it achieved its objectives. This approach assessed the project's results in relation to the stated objectives.To evaluate the model and determine its quality,Pilot testing was not conducted in real-world operational situations due to delays in obtaining approval from NTSA. Instead,we developed a bench-top prototype and tested it using simulated load inputs. The results of the evaluation are presented in Table 13.

5.3 Conclusion

This project successfully developed a microcontroller-based model to monitor and control vehicle overloading, addressing the persistent challenge of overloaded vehicles that significantly contribute to Kenya’s high rate of road accidents and annual economic losses estimated at over Kshs 300 billion. The proposed system demonstrated that automation can effectively minimize human dependency in enforcement, one of the key weaknesses identified in existing manual systems.

Through the integration of load sensors, a 24-bit ADC, and an STM32 microcontroller, the model achieved reliable weight measurement and real-time data processing, directly fulfilling the objectives of designing an accurate, automated, and low-cost overload monitoring system. The inclusion of wireless communication further enabled remote reporting for timely enforcement actions.

While the prototype effectively validates the feasibility of technology-driven overload control, future work should focus on enhancing scalability through IoT-based cloud integration**,** AI-driven data analytics, and solar-powered systems for remote operation. These improvements will ensure continuous, large-scale deployment and integration with national transport management systems, thereby strengthening road safety and compliance.

In conclusion, the study confirms that eliminating human dependency through smart, automated microcontroller-based systems is the most sustainable pathway toward reducing vehicle overloading and achieving safer, more efficient transportation networks.

5.4 Recommendations

5.4.1 Policy Recommendations

The Fourth Industrial Revolution (4IR) is a technological wave of change currently sweeping the globe. The 4IR's core enabling technologies include cloud computing, ICT, IoT, and big data. The effects of 4IR on education and transportation are two examples of its societal effects. Instead of falling behind, the Kenyan government should enhance its current ICT policy and motor vehicle importation policy to ensure that vehicles meet a minimum automation threshold, particularly in accordance with the manufacturer's design and traffic regulations.

5.4.2 Recommendation for Further Research

The integrated model for vehicle overload prevention based on microcontroller technology employs a proactive approach, rather than the current systems that use a reactive approach. If deployed, it has the potential to prevent vehicle overloading. The researcher recommends that the government upscale this research to allow for quicker deployment. The researcher recommends that the government create public awareness and conduct stakeholder training to facilitatea smooth transition and adaptability of the technology.

Future work should involve real-world testing on actual vehicles, ideally in collaboration with regulatory agencies, to validate the system's performance, reliability, and potential for large-scale deployment. There is also a need to undertake further studies on the security of these smart devices, as well as data science, to cater to the huge amount of data collected from vehicles.

To ensure that vehicles currently on the market are modified to meet the new automation threshold, it is also necessary to reassess the current policy.

Publication of the work

The work was presented at the following forums and conferences

a) CUK see the certificate of participation (appendix XX)

b) Kabarak University conference held on 9th October 2020 See abstract (Appendix viii)

c) Kenya National Research Festival Commendation Letter (Appendix x)

d) Kenya National Research Festival Exhibitors' badge (Appendix ix)

REFERENCES

Ågerfalk, Pär J. "Stimulating Academic Discourse: A Call for Response." *European Journal of Information Systems*, vol. 28, no. 1, 18 Dec. 2018, pp. 1–5, https://doi.org/10.1080/0960085x.2019.1557853. Accessed 19 Jan. 2021.

Al-Fuqaha, Ala, et al. "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications." *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, 2020, pp. 2347–2376.

Benson A., Ken W., Rushdie O., Wesonga D., Odiwuor G., Amadala B., (2019). B. Team What laws? Full-blown matatu chaos returns. *Business Daily*, Nairobi, Retrieved October09, 2019, from: https://www.businessdailyafrica.com/bd/data-hub/what-laws-full-blown-matatu-chaos-returns-2267172

Bonnet E, Lucie Lechat, Valéry Ridde (2019): What interventions are required to reduce road traffic injuries in Africa? A scoping review of the literature

Bonnet, E., et al. "What Interventions Are Required to Reduce Road Traffic Injuries in Africa? A Scoping Review of the Literature." *PLOS ONE*, vol. 13, no. 11, 30 Nov. 2018, p. e0208195, https://journals. plos.org/pl osone/a rticle? id=1 0.13 71/jo urnal. pone.0208195

Bucsuházy K., E. Matuchová, R. Zůvala, P. Moravcová, M. Kostíková, and R. Mikulec, "Human factors contributing to the road traffic accident occurrence," *Transportation Research Procedia*, vol. 45, pp. 555–561, 2020

Burnos, Piotr, et al. "High Accuracy Weigh-In-Motion Systems for Direct Enforcement." *ensors*, vol. 21, no. 23, 1 Dec. 2021, p. 8046, https://doi.org/10.3390/s21238046.

Decree of the State Council No.493. "Report of manufacturing safety accident and investigation processing by law". State Council of the People's Republic of China, Beijing [In Chinese]. 2007

Elahi,(2018) *Digital Design, Fundamentals of ComputerArchitecture and Assembly Language*1sted,SpringISBN 978-3-319-66774-4 ISBN 978-3-319-66775-1 (eBook) https://doi.org/10.1007/978-3-319-66775-1

Electric Motor Drives and their Applications with Simulation Practices, Academic Press, 2022, Pages 505-507, ISBN9780323911627, https://doi.org/10.1016/B978-0-323-91162-7.00181-8.

Foster, C. (2024) 'Methodological pragmatism in educational research: from qualitative-quantitative to exploratory-confirmatory distinctions', *International Journal of Research and Method in Education*, 47(1), pp. 4-19–19

Godfrey kayombo & Peter Kambosha (2019): Development of Passengers Vehicle Overloading Control System. International Journal of Engineering Research And Advanced Technology, Vol.5, Issue 8, August-2019

Heever, Maryna Van Den. "LibGuides: Research Support: Home." *Libguides.wits.ac.za*, 23 July 2024, libguides.wits.ac.za/research-support.

Herselman, M and Botha, A. 2015. Evaluating an Artifact in Design Science Research. In:SAICSIT 2015 Conference, Stias Wallenberg Centre, Stellenbosch, South Africa, 28 - 30 September 2015

Humble, Niklas , and Peter Mozelius (2023). “Design Science for Small Scale Studies: Recommendations for Undergraduates and Junior Researchers.” *Vol. 22 No. 1 (2023): European Conference on Research Methodology for Business and Management Studies*, 6 Sept. 2023.

Information Systems” January 20, 2004 (created in 2004 and updated until 2015 by Vaishnavi,V. and Kuechler, W.); last updated (by Vaishnavi, V. and Petter, S.), December 20, 2017. URL:

J. Jeswin Arputhabalan, M. Balachandar, T. Asaithambi, E. Balakrishnan, A. Ponshanmugakumar and B. Gunaseelan, "Microcontroller-Based Auto Lock Ignition System for Vehicle Overload Prevention," *2024 International Conference on Communic ation, Computing and Internet of Things (IC3IoT)*, Chennai, India, 2024, pp. 1-4, doi: 10.1109/IC3IoT60841.2024.10550355.

John X.J. Zhang, Kazunori Hoshino, in Molecular Sensors and Nanodevices (Second Edition), 2019

Jon, Kolko. “Jon Kolko - Sensemaking and Framing: A Theoretical Reflection on Perspective in Design Synthesis.” *Jon Kolko*, 7 Mar. 2009, www.jonkolko .com/w riting/sensemaking-and-framing. Accessed 13 Feb. 2023.

Jones, William. “Introduction to 20x4 LCD Module.” *The Engineering Projects*, 3 Dec. 2019,www.theengineeringprojects.com/2019/12/introduction-to-20-x-4-lcd-module.html. Accessed 25 Aug. 2021

Joseph Kamau Muguro1, Minoru Sasaki, Kojiro Matsushita&Waweru Njeri(2020 Trend analysis and fatality causes in Kenyan roads: A review of road traffic accident data between 2015 and 2020

K. S. Praveena, M. Prajwal, K. Bhargavi and M. R. Darshan, "An Automatic Overloaded Vehicle Monitoring and Prevention System using IoT," *2021 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT)*, Bangalore, India, 2021, pp. 788-792, doi: 10.1109 /RTEICT52294.2021.9573892.

Kaur, Barinder, et al. “Improved Content-Based Image Retrieval Technique for Query Generation in Mobile Networks.” *International Journal of Engineering and Advanced Technology*, vol. 9, no. 6, 30 Aug. 2020, pp. 526–530, https://do i.org/ 10.35940/ijeat.f1626.089620. Accessed 8 Mar. 2025.

Kendig, Catherine Elizabeth. “What Is Proof of Concept Research and How Does It Generate Epistemic and Ethical Categories for Future Scientific Practice?” *Science and Engineering Ethics*, vol. 22, no.3 1June 2016,pp 735–753, www .ncb i.nlm.nih.gov/pubmed/26009258, https://doi.org/10.1007/s11948-015-9654-0

Kenya anti corruption commission. *System,Policies,Procedures and Practices Inthe Registration and Licenses of Motor Vehicles and Enforcement of Traffic Laws*. Feb. 2006.

Kenya National , Bureau of statistics . “Economic Survey 2019.” Kenya National Bureau of Statistics, 2019. https://www.knbs.or.ke/reports/2019-economic survey/ accessed on March 6th, 2025

Kenya National Highways Authority (KeNHA). “KENHA Annual Report 2020–2021: Monitoring of axle load through Static,Weigh-in-Motion and Virtual Weigh Stations (VWS).” June 2022.

Kilavo Hassan et al (2013): Overview on passengers overload control in public buses case study:Tanzania .*International Journal of Engineering And Computer* Science ISSN:2319-7242.Volume2 Issue 8 August, 2013 Page No. 2536-2540

Liu G, Chen S, Zeng Z, Cui H, Fang Y, Gu D, et al. (2018): Risk factors for extremely serious. road accidents: Results from national Road Accident Statistical Annual Report of China. PLoS ONE 13(8): e0201587. https://doi.or g/10.13 71/ journal.pone.0201587

Manyara (2016) Combating Road Traffic Accidents in Kenya: A Challenge for an Emerging *Economy.*

Mazidi, M.A., & Mazidi, J.G. (1999): *The 8051 Microcontroller and Embedded Systems with Disk.*

McCombes, Shona. "What Is a Research Design | Types, Guide & Examples." *Scribbr*, 7 June 2021, www.scribbr.com/research-process/research-design.

Mogambi, H., & Nyakeri, F. (2015): Media priming of road traffic accidents in Kenya: Praxis, https://doi.org/10.1177/2158244015606491 [Crossref], [Web of Science ®], [Google Scholar].

Moh. Khairudin, et al. "Attadance System Using Infrared Sensors." *Journal of Physics*, vol. 1456, no. 1, 1 Jan. 2020, pp. 012012–012012, https://doi.org/10.1088/1742-6596/1456/1/012012. Accessed 2 Sept. 2023.

Moritz, et al. "Enhancing Weigh-In-Motion Systems Accuracy by Considering Camera-Captured Wheel Oscillations." *Sensors*, vol. 24, no. 24, 20 Dec. 2024, pp. 8151–8151, https://doi.org /10.3390/s24248151. Accessed 29 Apr. 2025.

Muguro J.K, M. Sasaki, K. Matsushita, W. Njeri (2022):Road traffic conditions in Kenya:Exploring the policies and traffic cultures from unstructured user-generated data using NLP

Muhammad Azrul. "Internet of Things (IoT) - SMART AGRICULTURE." *YouTube*, 7 Dec. 2016, www.youtube.com/watch?v=j4HBlOf5ZDA. Accessed 8 Mar. 2025

Muthukumaran Sonya (2017): Principles of wireless communications Scholas'press Myles Brown 2019 https://www.exitcertified.com/blog/4-cloud-computing-services C. L. Dos Santos Romeiro Júnior, L. A. Teixeira Brito, L. F. Heller et al., "Impact on pavement deterioration due to overload vehicle regulation in Brazil," *Transportation Research Procedia*, vol. 45, pp. 842–849, 2020. Retrieved on March 6th 2025

Odero W, Garner P, Zwi A(1997). Road traffic injuries in developing countries: a comprehensive review of epidemiological studies. Trop Med Int Health1997; 2:445–460. pmid:9217700

Odonkor, Ebenezer Narh, and Willie K. Ofosu. "Design and Construction of Vehicle Loading Monitoring System Using Load Sensor and GSM." *International Journal of Applied Science and Technology*, vol. 10, no. 1, 2020, https://doi.org/10.30845/ijast.v10n1p1. Accessed 1 Dec. 2021.

President Uhuru Kenyatta, ‘Speech addressed to the national police service’, 16 January 2017 Real Time Vehicle Overload Detection and Prevention", International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN:2349-5162, Vol.5, Issue 5, page no.149-154, May-2018, Available :http:// www.jetir.org/papers/JETIR18IC033.pdf

R. of K. (GoK). (2018): Traffic Act (Act No. CAP. 403). KenyaLaw.org. http://ke nyala w.org:8181/exist/kenyalex/actview.xql?actid=CAP.403#part_IX [Google Scholar]

Rodrigue, J-P et al. (2020), The Geography of Transport Systems, Fifth Edition, Hofstra University, Department of Global Studies & Geography New York: Routledge, https://transportgeography.org.

Sabah, Ahmed. “PI Controller for the Heating Process in the Real Time System Based on LAB VIEW 8.2 Packages.” *Engineering and Technology Journal*, vol. 27, no. 15, 1 Nov. 2009, pp. 2775–2791, https://doi.org/10.30684/etj.27.15.7. Accessed 29 Oct. 2024.

Sete Abebe, W. — *Design and Development of Vehicle-Mounted Excessive Passenger Loading Control System* (SSRN / 2023–2024 preprint).

Ştefãnescu, D. M. "Strain gauges and Wheatstone bridges — Basic instrumentation and new applications for electrical measurement of non-electrical quantities," Eighth International Multi-Conference on Systems, Signals & Devices, 2011, pp. 1-5, doi: 10.1109/SSD.2011.5767428.

Suresh Chinnathampy, M., et al. “Antenna Design: Micro Strip Patch for Spectrum Utilization in Cognitive Radio Networks.” *Wireless Personal Communications*, vol. 119, no. 1, 21 Feb. 2021, pp. 959–979, https://doi.org/10.1007/s11277-021-08232-6. Accessed 15 Oct. 2024

Tariku Sinshaw (2017): Designing Of Overload Monitoring System In Public Transportation Based On Microcontroller in Ethiopia International Journal Of Scientific& Technology Research Volume 6, ISSUE 10, OCTOBER 2017 ISSN 2277-8616

Transparency International, Kenya. *Traffic Legislation Gaps And Drivers Of Corruption In Traffic Matters*. 27 May 2018.

Vinand M N.& Michael R R. (2002): The neglected epidemic: road traffic injuries in developing countries, BMJ. 2002 May 11; 324(7346): 1139–1141. doi: 10.113 6/ bmj.324.7346.1139, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1123095/

vom Brocke, Jan, and Alexander Maedche. “The DSR Grid: Six Core Dimensions for Effectively Planning and Communicating Design Science Research Projects.” *Electronic Markets*, vol. 29, no. 3, 29 July 2019, pp. 379–385, https://doi .org/10.1 007/s12525-019-00358-7. Accessed 8 Jan. 2020.

World Health Organization. “Global Status Report on Road Safety 2018.” *World Health Organization*, 2018, www.who.int/publications/i/item/9789241565684. Accessed 8 Jan. 2025.

World Health Organization. “Global Status Report on Road Safety 2018.” *World Health Organization*, 2018, www.who.int/publications/i/item/9789241565684. Accessed 8 Jan. 2025.

Yi-Hsin Lin, Suyu Gu, Wei-Sheng Wu, Rujun Wang, Fan Wu, "Analysis and Prediction of Overloaded Extra-Heavy Vehicles for Highway Safety Using Machine Learning", *Mobile Information Systems*, vol. 2020, Article ID 6667897, 20 pages, 2020. https://doi.org/10.1155/2020/6667897 vol. 29, no. 3, 29 July 2019, pp. 379–385, https://doi.org/10.1007/s12525-019-00358-7. Accessed 8 Jan. 2020.

Yi-Hsin Lin, Suyu Gu, Wei-Sheng Wu, Rujun Wang, Fan Wu, "Analysis and Prediction of Overloaded Extra-Heavy Vehicles for Highway Safety Using Machine Learning", *Mobile Information Systems*, vol. 2020, Article ID 6667897, 20 pages, 2020. https://doi.org/10.1155/2020/6667897

Zhou., et al.*Truck model recognition for an automatic overload detection system* 2023Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC10448051/

APPENDICES

Appendix I: Source Codes

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SD.h>
#include <SPI.h>
#define ENA 5
#define ENB 6
#define SCK 2
#define DT 3
#define switchIgnite 7
#define sensorA 8
#define sensorB 9
int8_t countr = 0;
int8_t prevCountr = 0;
int8_t maximmCountr = 8;
boolean stateA = true;
boolean stateB = true;
boolean goodWide = false;
boolean enddWide = false;
boolean enddThin = false;
unsigned long timeValu = 0;
unsigned long prevTime = 0;
int mass;
int prevMass = 0;
float maximmWeight = 1200.0;
uint8_t motrSped = 125;
int cs = 10;
File myFile;
unsigned long waitTime = 58880;
unsigned long currentTime = 0;
```

```
unsigned long igniteTime = 0;
unsigned long saveTime = 0;
boolean sdstate = false;
boolean sdUpdate = false;
boolean sdFrst = true;
boolean countrExceed;
boolean weightExceed;
boolean runMot = false;
boolean sndMas = false;
boolean sndCnt = false;
float SCALE = 231.f; // used to return weight in grams, kg
byte GAIN = 1;    // amplification factor channel A, gain factor 128
byte check[8] = {
  0b00000,
  0b00001,
  0b00011,
  0b10110,
  0b11100,
  0b01000,
  0b00000,
  0b00000
};

byte uncheck[8] = {
  0b00000,
  0b00000,
  0b10001,
  0b01010,
  0b00100,
  0b01010,
  0b10001,
  0b00000
};
```

```
LiquidCrystal_I2C LCD(0x27, 20, 4);

void setup() {
  Serial.begin(9600);
  delay(1000);
  pinMode(switchIgnite, INPUT_PULLUP);
  pinMode(sensorA, INPUT);
  pinMode(sensorB, INPUT);
  pinMode(ENA, OUTPUT);
  pinMode(ENB, OUTPUT);
  pinMode(SCK, OUTPUT);
  pinMode(DT, INPUT);
  pinMode(cs, OUTPUT);
  analogWrite(ENA, 0);
  analogWrite(ENB, 0);

  digitalWrite(SCK, LOW);
  HX711read();
  delay(1000);

  LCD.begin();
  LCD.createChar(0, check);
  LCD.createChar(1, uncheck);
  LCD.backlight();
  LCD.home();
  LCD.clear();
  LCD.setCursor(0, 0);
  LCD.print("Count :");

  LCD.setCursor(0, 1);
  LCD.print("Mass  :");
  LCD.setCursor(8, 0);
  LCD.print(countr);
  LCD.print("/");
```

```
  LCD.print(maximmCountr);
  exceedCountr();

  if (!SD.begin(cs)) {
    sdstate = false;
  }
  else {
    sdstate = true;

    if (!SD.exists("data.csv")) {
      myFile = SD.open("data.csv", FILE_WRITE);
      if (myFile) {
        myFile.println("Count,Mass,StartSwitch,VehicleStatus");

        myFile.close();// close the file:
      }
      else {
        sdstate = false;
      }
    }
  }
}
void loop() {
  readSensor(); // read the IR sensors data
  readMass(); // read the weight data
  exceedCountr(); // check if count or the weight is exceeded
  anlyseData(); // save the data to an SD card after each minute
}
void readProx() {
  stateA = digitalRead(sensorA);
  stateB = digitalRead(sensorB);
}
void readMass() {
  mass = HX711get_units(10);
```

```
  if (mass != prevMass) {
    LCD.setCursor(8, 1);
    LCD.print("          ");
    LCD.setCursor(8, 1);
    LCD.print(mass);
    LCD.print("/");
    LCD.print(int(maximmWeight));
    LCD.print("g");
    prevMass = mass;
  }
}
void readSensor() {
  readInward();
  readOutward()
  if (countr != prevCountr) {
    LCD.setCursor(8, 0);
    LCD.print("       ");
    LCD.setCursor(8, 0);
    LCD.print(countr);
    LCD.print("/");
    LCD.print(maximmCountr);
    exceedCountr();
    prevCountr = countr;
  }
}
void readInward() {
  readProx();
  if (!stateB) {
    while (true) {
      readProx();
      if (!stateA) {
        while (true) {
          readProx();
```

```
    if (!stateB && stateA) {
      enddWide = true;
      break;
    }

    if (stateB && !stateA) {
      goodWide = true;
    }
    if (stateB && stateA) {
      if (goodWide) {
        countr += 1;
        if (countr > 8) {
          exceedCountr();
        }
        enddWide = true;
        break;
      }
      enddWide = true;
      break;
    }
  }
}
if (enddWide) {
  break;
}
if (stateB) {
  timeValu = millis();
  while ((millis() - timeValu) <= 400) {
    if (!digitalRead(sensorA)) {
      countr += 1;
      break;
    }
    enddThin = true;
  }
```

```
      }

      if (enddThin) {
        break;
      }
    }
  }
  goodWide = false;
  enddWide = false;
  enddThin = false;
}
void readOutward() {
  readProx();
  if (!stateA) {
    while (true) {
      readProx();
      if (!stateB) {
        while (true) {
          readProx();

          if (!stateA && stateB) {
            enddWide = true;
            break;
          }
          if (stateA && !stateB) {
            goodWide = true;
          }
          if (stateA && stateB) {
            if (goodWide) {
              countr -= 1;

              if (countr <= 0) {
                countr = 0;
              }
```

```
            enddWide = true;
            break;
          }
          enddWide = true;
          break;
        }
      }
    }
    if (enddWide) {
      break;
    }
    if (stateA) {
      timeValu = millis();
      while ((millis() - timeValu) <= 400) {
        if (!digitalRead(sensorB)) {
          countr -= 1;
          if (countr <= 0) {
            countr = 0;
          }
          break;
        }
        enddThin = true;
      }
    }
    if (enddThin) {
      break;
    }
  }
}
goodWide = false;
enddWide = false;
enddThin = false;
}
```

```
void exceedCountr() {
  countrExceed = countr > maximmCountr;
  weightExceed = mass > maximmWeight;

  if (countrExceed) {
    LCD.setCursor(19, 0);
    LCD.write(byte(1));
  }
  else {
    LCD.setCursor(19, 0);
    LCD.write(byte(0));
  }
  if (weightExceed) {
    LCD.setCursor(19, 1);
    LCD.write(byte(1));
  }
  else {
    LCD.setCursor(19, 1);
    LCD.write(byte(0));
  }
  if (!countrExceed) {
    sndCnt = true;
  }
  if (!weightExceed) {
    sndMas = true;
  }
  if (countrExceed || weightExceed) {
    wheelsStatus(" Vehicle stopped  ", 0);
    runMot = false;
    if ((sndMas || sndCnt) && countrExceed && weightExceed) {
      sndCnt = false;
      sndMas = false;
      sendMess("Mass : " + String(mass) + "\nCount : " + String(countr));
```

```
    }
    else if (sndCnt && countrExceed) {
      sndCnt = false;
      sendMess("Count : " + String(countr));
    }
    else if (sndMas && weightExceed) {
      sndMas = false;
      sendMess("Mass : " + String(mass));
    }
  }
  else {
    if (!digitalRead(switchIgnite) && (millis()-igniteTime)>2000) {
      runMot = !runMot;
      igniteTime = millis();
    }
    if (runMot) {
      wheelsStatus(" Vehicle running  ", motrSped);
    }
    else {
      wheelsStatus("Press start switch", 0);
    }
  }
}
long HX711read() {
  // wait for the chip to become ready
  while (digitalRead(DT)) {
    // Will do nothing on Arduino but prevent resets of ESP8266 (Watchdog Issue)
    readSensor();
    yield();
  }
  unsigned long value = 0;
  uint8_t data[3] = { 0 };
  uint8_t filler = 0x00;
```

```
  // pulse the clock pin 24 times to read the data
  data[2] = shiftIn(DT, SCK, MSBFIRST);
  data[1] = shiftIn(DT, SCK, MSBFIRST);
  data[0] = shiftIn(DT, SCK, MSBFIRST);
  // set the channel and the gain factor for the next reading using the clock pin
  for (unsigned int i = 0; i < GAIN; i++) {
    digitalWrite(SCK, HIGH);
    digitalWrite(SCK, LOW);
  }
  // Replicate the most significant bit to pad out a 32-bit signed integer
  if (data[2] & 0x80) {
    filler = 0xFF;
  } else {
    filler = 0x00;
  }
  // Construct a 32-bit signed integer
```

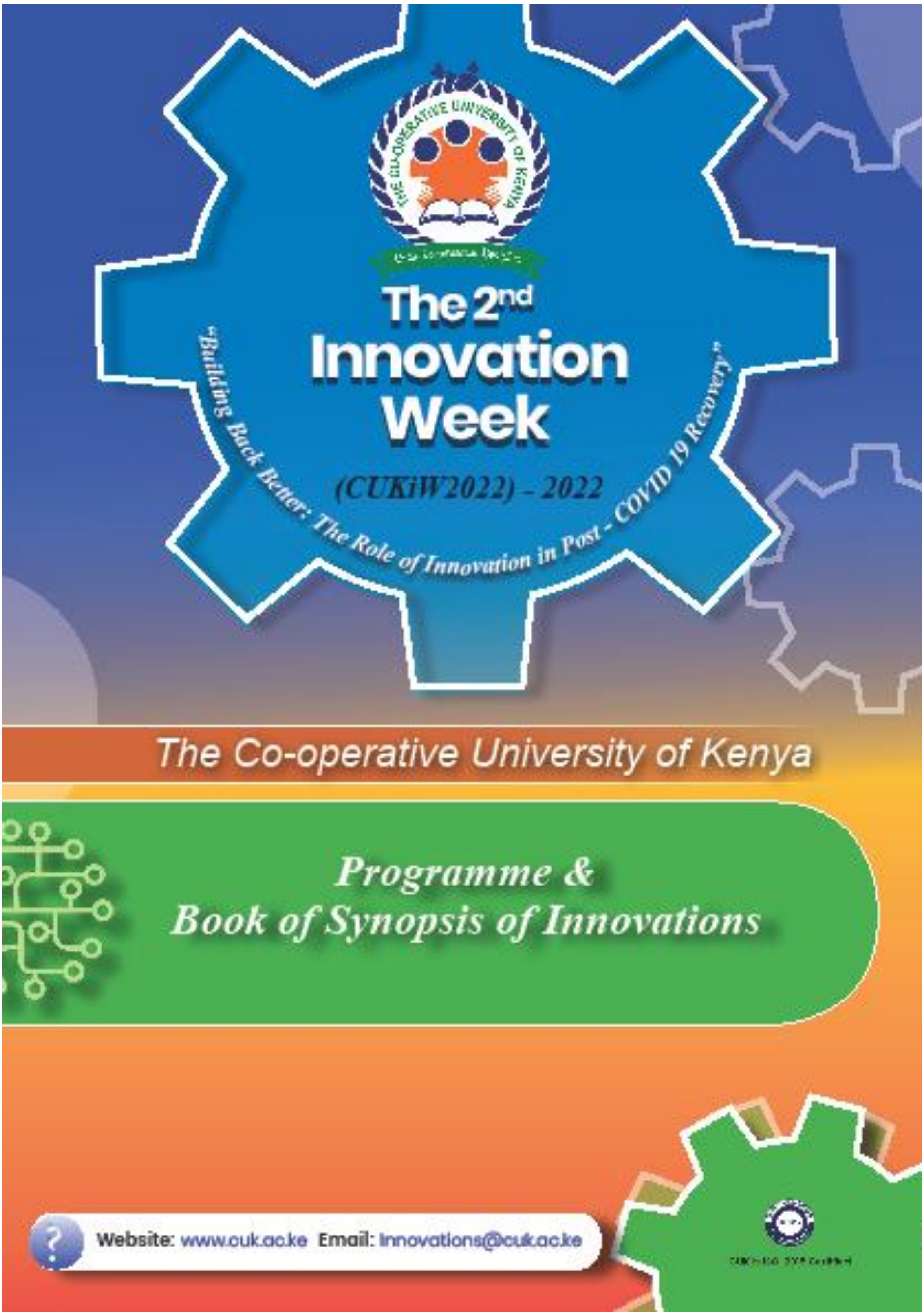
value = (static_cast<unsigned long>(filler) << 24

```
      | static_cast<unsigned long>(data[2]) << 16
      | static_cast<unsigned long>(data[1]) << 8
      | static_cast<unsigned long>(data[0]) );

  return static_cast<long>(value);
}

long HX711get_units(byte times) {
  long sum = 0;
  for (byte i = 0; i < times; i++) {
    sum += HX711read();
    readSensor();
    yield();
  }
  return sum / (times * SCALE);
```

```
}

void anlyseData() {

  if (sdstate) {

    currentTime = millis();
    if (((currentTime - saveTime) >= waitTime) || sdFrst) {
      sdFrst = false;
      myFile = SD.open("data.csv", FILE_WRITE);
      if (myFile) {
        myFile.print(countr);
        myFile.print(",");
        myFile.print(mass);
        myFile.print(",");
        myFile.print(!digitalRead(switchIgnite));
        myFile.print(",");
        myFile.println(!countrExceed && !weightExceed && !digitalRead(switchIgnite));

        myFile.close();// close the file:

        if (sdUpdate) {
          LCD.setCursor(4, 3);
          LCD.print("            ");
          sdUpdate = false;
        }
      }
      else {
        LCD.setCursor(4, 3);
        LCD.print("Insert an SD");
        sdstate = false;
      }
      saveTime = millis();
    }
```

```
  }
  else {
    if (!sdUpdate) {
      LCD.setCursor(4, 3);
      LCD.print("Insert an SD");
      sdUpdate = true;
    }
  }
}
void wheelsStatus(String vehSts, uint8_t spd) {
  analogWrite(ENA, spd);
  analogWrite(ENB, spd);
  LCD.setCursor(1, 2);
  LCD.print(vehSts);
}
void sendMess(String txtMsg) {
  Serial.println("AT+CMGF=1");
  delay(80);
  Serial.println("AT+CMGS=\"+254722337962\"");
  delay(80);
  Serial.print(txtMsg);
  delay(80);

  Serial.write(26);

}
```

Appendix II: The 2nd Innovation Week (CUKiW2022)-2022



Appendix III: Expert Opinion

Pixel
Engineering Africa Limited

www.pixelelectric.com

To James Ndungu

From Pixel Engineering Africa

Date 2024-02-28

Subject Feasibility of Implementing Overload Detection System in Actual Car for Thesis Demonstration

This report analyzes the feasibility of implementing the proposed overload detection system in an actual car for the client's thesis demonstration and explores alternative approaches using a prototype.

1. Challenges of Implementing the System in an Actual Car

Implementing the overload detection system in an actual car presents several significant challenges

- **Licensing and Approval Process**
    - In Kenya, modifying a vehicle significantly from its original design requires approval from the National Transport and Safety Authority (NTSA). This process involves various stages, including
        - Application submission with detailed modification plans and justifications.
        - Vehicle inspections by NTSA-approved engineers.

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        - Potential modifications to comply with safety regulations.
        - Final approval and issuance of a certificate of modification.
    - Each stage incurs costs, and the entire process can take several months, significantly exceeding the typical timeframe for a thesis project.
- **Cost and Risks**
    - Integrating the system into an actual car necessitates purchasing and installing industrial hardware like sensors, controllers, and displays. This can be expensive, especially considering the potential need for modifications to accommodate new components.
    - Testing the system in a real-world environment carries risks of malfunction, damage to the vehicle, and potential safety hazards.

2. Prototype Advantages and Scalability

While implementing the system in an actual car poses significant challenges, utilizing a well-designed prototype offers several advantages

- **Cost-Effectiveness** Prototypes typically use readily available components and simpler designs, significantly reducing cost compared to modifying an actual car.
- **Safety** Prototypes operate in a controlled environment, minimizing risks associated with real-world testing.

- **Scalability** The principles and functionalities tested in the prototype can be translated to actual car components during future implementation.

3. Workability and Problem Solving

The proposed system addresses the critical issue of overloading in PSVs and on railway tracks, leading to potential safety hazards, vehicle damage, and infrastructure degradation. By integrating bidirectional IR sensors and load sensors, the system can

- **Detect passenger and cargo overload in PSVs, preventing unsafe conditions.**
- **Monitor track load on railways, alerting authorities to potential infrastructure issues.**

The prototype demonstrates the feasibility of the system's core functionalities, providing valuable proof-of-concept for future real-world implementation.

4. Recommendations and Considerations

While implementing the system in an actual car is currently not feasible due to the aforementioned challenges, we recommend the following

- **Focus on refining the prototype** Enhance the prototype by incorporating features like
    - User interface for setting parameters and displaying overload warnings.

    - Integration with additional sensors for comprehensive data collection (e.g., weight sensors for PSVs).
- **Highlight scalability in the thesis** Emphasize how the design and functionality tested in the prototype can be translated to actual car components during future implementation.
- **Consider alternative funding options** Explore potential funding sources like research grants or collaborations with companies interested in the technology for further development and practical application.

5. Conclusion

Implementing the overload detection system in an actual car for the client's thesis demonstration is currently not feasible due to the complex and time-consuming licensing and approval process. However, focusing on refining a well-designed prototype and emphasizing its scalability can effectively showcase the system's potential and pave the way for future real-world implementation with appropriate funding and resources.

Appendix IV: Research Approval from Laikipia University

LAIKIPIA UNIVERSITY

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NYAHURURU,
KENYA

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Cell: +254 722478916
rec@laikipia.ac.ke; www.laikipia.ac.ke

DIRECTORATE OF RESEARCH, HUMAN RIGHTS AND GENDER

27th August, 2024

LU/ACA/RHG/7/VOL 1/102

To: Mr. James Ndungu Njuguna
Laikipia University

Dear Mr Njuguna,

RE: COMMENDATION FOR INNOVATION PRESENTATION DURING THE 2024 KENYA NATIONAL RESEARCH FESTIVAL.

The Directorate of research, gender and human rights wishes to congratulate you for presenting your innovation product during the above referred festival which took place in Nairobi from 19th to 23rd August, 2024.
Your participation during the event raised the profile of Laikipia University in the world of Academia within and outside Kenya. Please keep up this spirit. The University will continue to support you for such a presentation in future.
Once again, thank you and all the best.

Thank you.

Yours Sincerely.

Prof. John Kanjogu. PhD
DIRECTOR
Cc DVC (ARSA)

Vision: *Nurture and Transform for the World.*
Mission: *To contribute to the world through Education, Research, Training, Consultancy, Innovation, Outreach, and Collaboration.*

Laikipia University is ISO 9001:2015 and ISO/IEC 27001:2013 Certified
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Appendix V: KUREC Clearance Letter

KABARAK UNIVERSITY RESEARCH ETHICS COMMITTEE

Private Bag - 20157
KABARAK, KENYA
Email: kurec@kabarak.ac.ke

Tel: 254-51-343234/5
Fax: 254-051-343529
www.kabarak.ac.ke

OUR REF: KABU01/KUREC/001/02/02/25

Date: 5th Feb, 2025

James Ndungu Njuguna
Reg No: GMI/NE/0273/01/19
Kabarak University,

Dear James,

RE: AN INTEGRATED MODEL TO PREVENT OVERLOADING OF VEHICLES BASED ON MICRO-CONTROLLER.

This is to inform you that ***KUREC*** has reviewed and approved your above research proposal. Your application approval number is ***KUREC-020225.*** The approval period is ***5/02/2025 – 5/02/ 2026.***

This approval is subject to compliance with the following requirements:

i. All researchers shall obtain an introduction letter to NACOSTI from the relevant head of institutions (Institute of postgraduate, School dean or Directorate of research)
ii. The researcher shall further obtain a RESEARCH PERMIT from NACOSTI before commencement of data collection & submit a copy of the permit to **KUREC.**
iii. Only approved documents including (informed consents, study instruments, MTA Material Transfer Agreement) will be used
iv. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***KUREC***:
v. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***KUREC*** within 72 hours of notification;
vi. Any changes, anticipated or otherwise that may increase the risk(s) or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KUREC*** within 72 hours;
vii. Clearance for export of biological specimens must be obtained from relevant institutions and submit a copy of the permit to KUREC;
viii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal and;
ix. Submission of an executive summary report within 90 days upon completion of the study to ***KUREC***

Sincerely,

Prof. Jackson Kitetu PhD.
KUREC-Chairman

KABARAK UNIVERSITY
INSTITUTIONAL RESEARCH ETHICS COMMITTEE
05 FEB 2025
APPROVED
P. O. PRIVATE BAG - 20157, KABARAK

Cc
Vice Chancellor
DVC-Academic & Research
Registrar-Academic & Research
Director-Research Innovation & Outreach
Institute of Post Graduate Studies

As members of Kabarak family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord. (1 Peter 3:15)
Kabarak University is ISO 9001:2015 Certified

Appendix VI: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 421472

Date of Issue: 27/February/2025

RESEARCH LICENSE

This is to Certify that Mr.. James Ndungu Njuguna of Kabarak University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: AN INTEGRATED MODEL TO PREVENT OVERLOADING OF VEHICLES BASED ON MICRO-CONTROLLER. for the period ending : 27/February/2026.

License No: NACOSTI/P/25/416166

421472

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix VII: Evidence of Conference Participation

KABARAK UNIVERSITY

Certificate of Participation

Awarded to

James Njuguna

for successfully participating in the Kabarak University International Research Conference on Computing and information systems 2021 on 4th and 5th October 2021 and presented a paper entitled ***"An Integrated Model for Public Service Vehicles Overload Prevention Based on Micro-Controller."***

Conference Theme

Development, Protection And Commercialization Of Intellectual Property

Prof. Jackson Kitetu
Dean School of Science, Engineering and Technology

Dr. Moses Thiga
Director Research, Innovation and Outreach

Kabarak University Moral Code

As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.

(1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix VIII: List of Publication

Proceedings of the Kabarak University International Conference on the Basic Sciences, 9th October 2020 Nakuru, Kenya.

Design of an Integrated Model for Public Service Vehicles Overload Prevention Based on Micro-Controller.

James NDUNGU[1], Simon KARUME[1], Kirori MINDO[2]
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Tel: +254 0722337962, jamesnjuguna@ kabarak.ac.ke, +254 0722499397 skarume@kabarak.ac.ke
[2]*Laikipia University, P.O. Box 1100 – 20300, Nyahururu, Kenya*
Tel: + 254 721 864 816, kirori@laikipia.ac.ke

Abstract: The load capacity of a PSV vehicle is normally determined by tare weight and not the available cargo space as stated in section 56 of the Traffic act Cap 403, Kenya. Unfortunately, law enforcers on Kenyan roads only check the number of passengers in a PSV vehicle. This can be misconstrued to deem the PSV vehicle as compliant, while in real sense the actual tare weight is above its capacity. There are numerous instances where PSV vehicles are overloaded, and this has a direct contribution to increased road carnage. This study examined the implementation of an integrated microcontroller-based technology to observe and monitor tare weight in the PSV industry and introduced solutions that might resolve the misconception of overloading, while enhancing safety within the industry. This study provides the design of an integrated model for prevention of PSV overloading using a smart microcontroller. The resulting design was tested using Arduino microcontroller environment for purposes of validating applicability and feasibility. The study uses a proof of concept (POC) methodology and contributes to the body of knowledge in automated and integrated micro-controller-based safety monitoring industry.

Keywords: PSV, Tare weight, Overloading, Micro-controller.

1. Introduction

Transport is a major sector of any nation's economy (Rodrigue, J-P et al., 2020). Worldwide, the transport sector is a major employer as stated by Rodrigue, (2020), that an efficient transport system provide economic and other benefits that result in positive multiplier effects such as better accessibility to markets, employment, and additional investments. The Kenyan transport sector has recently expanded due to heavy infrastructure investments by the government and international entities. According to Kenya National Bureau of Statistics (KNBS,2019), the sector is the second highest contributor to the Gross Domestic Product (GDP) contributing about 8% after agriculture, forestry and fishing at 34.2%.

In spite of its importance in economic contribution, the transport systems can have serious economic costs when they are deficient in terms of capacity or reliability (Rodrigue, J-P et al., 2020). For instance, deficient transport system can result to economic costs such as reduced or missed opportunities and lower quality of life in case of accidents. According to the world health organization Global status report on road safety (WHO, 2018), Road traffic injuries are a leading cause of death, killing nearly 1.35 million people annually. Approximately 90% of these deaths occur in low- and middle-income countries of which Kenya is included. As stated by Liu G. et al. (Liu G. et al 2018), there is need for comprehensive research in the causes of road accidents as they are a public health issue worldwide. Further Liu et al. (Liu et al 2018) observed that there is need to pay special attention to extremely serious road accidents (ESRAs). ESRAs are considered to be traffic