Final Year Project Report

Snap Pick

AR-Based Warehouse Management System (WMS)

By

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DECLARATION

We hereby declare that this project report entitled "**Snap Pick**" submitted to the "**School of Electrical Engineering and Computer Science (SEECS)**", is a record of an original work done by us under the guidance of Supervisor "**Ms. Zunera Zahid**" and that no part has been plagiarized without citations. Also, this project work is submitted in the partial fulfilment of the requirements for the degree of Bachelor of Software Engineering.

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DEDICATION

This is a dedication message to express our heartfelt gratitude to our advisors, i.e., **Ms**. **Zunera Zahid**, **Dr. Mujtaba Agha, Dr. Seema Jehan** and **Dr. Nazia Pervaiz**, for their unwavering support and guidance throughout the course of the project. Their insightful comments, constructive feedback, and thoughtful suggestions have been instrumental in shaping the development and success of this work

We are deeply grateful for their dedication to academic excellence, their tireless efforts to nurture and inspire young minds, and their commitment to creating an environment that fosters learning and growth. It is with great admiration and appreciation that we dedicate this report to them, as a testament to their unwavering commitment to education and their unwavering support for their students.

We would also like to express our deepest gratitude to the entire faculty of **National University of Sciences & Technology (NUST)** for their invaluable contributions to this project and for the impact they have had on our academic and personal development as a whole.

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DEFINITIONS AND ACRONYMS

Term	Definition
Warehouse Management System (WMS)	Software solution that offers visibility into a business' entire inventory and manages supply chain fulfillment operations
Order Picking	Products listed in an order are retrieved from their respective locations
Augmented Reality	Type of technology that makes use of computer vision, superimposing visual, auditory, and other sensory information onto the physical world, to enhance user experience.
Inventory	The goods or materials a business intends to sell to customers for profit
DHL	DHL is an American founded, German logistics company providing courier, package delivery and express mail service.
Workers	Workers are the employees present in warehouse. These can be divided based on either their roles (picker or packager) or based on their status (temporary or permanent)
Manager	Primary user of this system, and the person responsible for supervising the dispatching and storage of goods
Picker	Picker is a type of worker that is responsible for order picking
Packager	Packager is a type of worker that is responsible for collating or packaging orders after they've been picked
Pick Bucket	Pick buckets are automatic order assignments to workers and are maintained based on zones of incoming orders. All items with same zone are assigned to one pick bucket, and a new pick bucket is created for every new zone.
Worker Status	Worker status can be divided into 5 types, i.e., available, picking, returning, packaging and unavailable.

Vision Picking	An order picking method in which the employee of the warehouse logistics is aided by visual information in their field of vision using AR
SKU	Stock Keeping Unit, used by retailers to identify and track inventory or stock
Inventory Status	Inventory status is divided into 2 types, in stock products or out of stock
Virtual Warehouse Map	The virtual replicate map of the warehouse fed into the system for indoor navigation
Indoor Navigation	Navigation system to determine the location of a device indoors
Marker-based tracking	Tracking that makes use of distinctive markers to check user position
QR Code	QR (quick response) code is a unique code that stores more information than barcodes
Visual Marker	An image or an object that can be recognized by an AR-enabled mobile app and is used to trigger augmented reality features
One handed User Interface	A mobile based feature that allows you to navigate your device more efficiently with one hand
Package Bins	Items are dumped into these bins according to their assigned order and bin number. After all items of the order have been picked and placed in the bin, the packager is notified to start the packaging process of that order
Order Status	Order status is of 4 types and is dependent on where the worker is with the order. These include pending (order received), in picking (worker is
Worker Type	Worker Type is of two categories, workers can be permanent or temporary
Zone	A physically or logically segregated area within a warehouse defined by the type of material it contains
Hot zone	Zone with items most in demand

ABSTRACT

The paper documents the use of “Snap Pick”, an app that employs Augmented Reality (AR) as a cost-effective solution to reducing pick time and package errors, by offering dynamic order handling using servers.

In a warehouse, an estimated of 60% cost can be attributed to order picking, which constitutes of picking products off shelves and dropping them to their required locations. Boosting work efficiency in this area is an important aim of logistics and the supply chain management (SCM) industry.

The team has done extensive research on the various value propositions AR has to offer, to support multiple warehouse operations. The app focuses on reducing cost and error-rate by helping managers keep track of the store’s inventory and personnel, while choosing picking schedules and processes which are most efficient for their specific system.

The process starts by first storing the systematic description of the shelves and inventory in an online database in the form of a global virtual map. Order assignment is done automatically by the deployed server based on the worker’s status and warehouse zones. Search time is reduced by illustrating visual elements on the picker’s phone, while dynamically guiding them through the shortest possible path from their location to the required destination. This location is tracked using the phone's accelerometer and gyroscope.

After picking up all items on the list, the picker is guided back to a collation desk where the packager collates all items based on order. All algorithms are run on the server to minimize processing on workers’ end.

The app design is kept general and is not only limited to warehouse operations, and can be extended to be used in any pick or package use-cases in real life, e.g., shopping, indoor navigation in malls, campus navigation, etc.

Keywords: *Augmented reality, Warehouse Management System, Cyber-physical systems, Global mapping, Marker Tracking IPS, Path finding, Picking Strategies*

1. INTRODUCTION

1.1. BACKGROUND

Augmented Reality or AR technology makes use of computer vision, superimposing visual, auditory, and other sensory information onto the physical world, to enhance user experience.
While the concept of augmented reality (AR) dates back to 1966, when Ivan Sutherland created his first head mounted display (HMD) (Liberati), its practical demand came decades later when software evolved, and developers could make proper use of computer vision for business processes.
While the top industry that claims AR is still the gaming industry, retail and logistics trail close behind. The number of research papers focusing on AR technologies applications in Supply Chain Management (SCM) and logistics continues to proliferate. (Mingweicao, 2020)
It's notable that AR pick-by-vision guidance is conducive to increased performance peak and reduced task load (Patrick Renner, 2020). Likewise, AR-enabled imaging has enabled companies to increase operational proficiencies, lower expenses, and become more adaptive to changes. AR enables logistics operators to attain more supervision over industrial processes and a high level of situational awareness. This capability is enabled by real-time generation of data throughout all steps in the supply chain.
AR can lead to development of a sustainable supply chain and contribute to upgrading working conditions of employees, process visibility, better workflow, and environmental awareness. These AR systems shall help project required information, enhance ergonomics at the workplace, and support human operatives in their objectives.

1.2. DOCUMENT CONVENTIONS

Defined terms are highlighted in **bold.**

1.3. INTENDED AUDIENCE AND READING SUGGESTIONS

This document is intended essentially for stakeholders among our potential industrial clients and our Final Year Project committee.

1.4. PROJECT SCOPE

The role of Warehouse management in modern logistics is becoming progressively essential as it influences the supply chain's ability to satisfy working continuity demands. **Order Picking** is an integral part of Warehouse management and is the most error-prone and costly operation for small and medium-sized warehouses.

Snap Pick is a mobile-based application that makes use of **Augmented Reality** as a means to minimize pick errors, optimizing these operations by replacing traditional paper-based pick lists with automated and optimized algorithms for assigning work to pickers.

Further, it also includes automation of basic warehouse management operations, i.e., **inventory** tracking and managing staffs' work assignment. This will allow for increased proficiency of workers as well as the manager, as reported by **DHL** services while implementing AR based tracking in their warehouses. *(DHL, 2015)*

1.5. PROBLEM STATEMENT

Retail, e-commerce, and other big industries have expressed demand for an efficient and accurate logistic service. The role of warehousing in modern logistics becomes progressively essential as it influences the supply chain ability to satisfy working continuity demands.

Inventory accounting can be a gruesome task, especially for large industries. Inaccurate inventory shows an ineffectual management system, which leads to disordered pick locations, unsatisfied customers, and delayed distribution of stock.

A major task in warehousing is to manage subsequent orders in specified time and at minimal monetary cost. Conventionally, paper lists are used to convey orders to company personnel. But this can be laborious to handle and lead to faults while manually scanning the paper list. Moreover, pick up orders cannot be updated in real time, as the paper lists are distributed prior to pick up operation.

Another impeding factor in warehousing is incorrectly collected orders. They result in additional working time and monetary expenses to organize returns. Moreover, the company's reputation is at stake with such blunders.

These human errors often occur due to missing or inappropriate labelling of stock. Labelling issues delay workers, slowing down their operating speed, and lowering performance. Therefore, for an efficient functioning, you need to adopt an appropriate management system.

High technology systems like AR and computer vision can facilitate workers in performing their routinely tasks more easily and quickly, resulting in increased productivity. Thus, the investment in implementing new methods of warehouse management instantly pays off.
With AR being a fast-growing innovation, it’s no surprise that all high-profile firms have demanded their organizational processes to incorporate AR solutions. The global AR market size was 4.16 billion USD in 2020, and is predicted to grow to a soaring 97.76 billion USD in 2028 at a CAGR (compound annual growth rate) of 48.6% in the 2021-2028 period (Report, 2022)

1.6. TARGET AUDIENCE

The target audience for this app is anyone who is interested in improving their warehouse operations by leveraging the latest technology. This could be warehouse owners and managers who want to increase their efficiency and accuracy in handling inventory, logistics and supply chain professionals who want to streamline their processes and reduce errors in the fulfilment process, retailers who want to reduce their stock-outs and improve their inventory accuracy to provide better customer service or third-party logistics providers who want to offer advanced solutions to their clients and improve their competitiveness in the market.

2. LITERATURE REVIEW

Prior to the design and implementation phase, a thorough investigation was conducted to explore all feasible methods of integrating Augmented Reality technology into warehouse environments. The aim of this research was to evaluate the various approaches available for the deployment of Augmented Reality, including hardware specifications, data retrieval techniques, scheduling algorithms, and pathfinding strategies.

By assessing the advantages and disadvantages of each method, keeping in mind the budget constraints and the country's current technological standing, an informed decision about the best suitable method was made.

2.1. INFORMATION INTER-CONNECTION METHODS

Common methods for information communication include:

- **Pick by RFID**: RFID tags can be considered a suitable choice for information interaction, which also aids in identifying object positions. Major benefits of RFID's include flexibility, high efficiency, and low cost. (Ginters E, 2011)
- **Pick by Voice**: Paperless, hands-free systems that makes use of natural language voice prompts to direct instructions to fulfilment workers guiding to specific locations in the warehouse for product retrieval. They are most commonly used along with RFID tags.
- **Pick to Light**: Essentially makes use of different coloured LED lights along with combinations of letters and numbers to direct workers to exact locations. However, these solutions can be considered costly for large scale warehouses.

2.2. WAREHOUSE PICKING STRATEGIES

Warehouse order picking strategies can optimize the rate at which orders are picked within a warehouse. These strategies can vary based on several factors which include size of the warehouse, variety of items stored in the warehouse and organizational choice. However, most common types of strategies are discussed below. (Pratik J. Parikh, 2008)

2.2.1. Zone Picking

Zone picking is a method of order picking in which the warehouse or distribution centre is divided into multiple zones, with each zone assigned to a different picker. Each picker is responsible for picking items from their assigned zone and passing them on to the next picker until all the items for the order have been collected.

In zone picking, each picker only handles a subset of the items needed for an order, which can help to reduce the amount of time spent traveling throughout the warehouse or distribution centre. This can be particularly useful in larger facilities where pickers may otherwise spend a significant amount of time traveling between different locations.

Zone picking can also help to improve accuracy, as each picker is only responsible for a subset of the items needed for an order, reducing the risk of confusion or errors. Additionally, zone picking can make it easier to track progress and identify bottlenecks in the order picking process.

2.2.2. Batch or Multi-Order Picking

This strategy is seen to be ideal for businesses that have a high repeated order rate. SKUs are placed based on their popularity in batches and pickers are assigned to those specific batches, pickers are best positioned ideally in this strategy speeding up the fulfilment process.

n batch picking, the picker will pick all the items needed for multiple orders at the same time, placing them in a single container or cart. Once all the items for the batch have been picked, the picker will sort them into individual orders at a later stage. Batch picking is generally considered to be more efficient than other methods of picking, as it allows pickers to minimize travel time and maximize the number of items picked per trip.

2.2.3. Wave Picking

In wave picking, orders are grouped together into batches and picked in waves, usually at scheduled intervals throughout the day. For example, all the orders that come in between 8 am and 10 am will be picked in a single wave, with subsequent waves for orders received later in the day. This method of picking is generally used when the volume of orders is too large to be picked all at once, or when order volumes vary throughout the day.

2.3. PATH FINDING ALGORITHMS

After workers are assigned to their respective zones or areas based on chosen pick strategy, an algorithm must be devised that ensures fastest path to the end destination point. To do that, we explored multiple shortest path algorithms, which are listed below.

2.3.1. Bellman Ford's Algorithm

The bellman ford algorithm is a form of greedy algorithm, normally used in dynamic programming for finding optimal routes. It works by calculating the overestimated length of the path from the starting vertex to all others. Then it iteratively relaxes those estimates by finding new paths that are shorter than the previously estimated paths.

An advantage of this algorithm is that it also accounts for negative weights. These albeit do not help in distance estimation, but can be used to determine cashflow, heat released/absorbed in chemical reactions, etc.

2.3.2. Dijkstra's Algorithm

This algorithm is very popularly used in distance or graph vector calculations for finding shortest path between any two vertices in the graph. It only differs from the minimum spanning tree as it doesn't include all vertices of the graph in all cases.

It basically works on the theory that any sub-path from point 2 to 3 from the path 1 to 3 between vertices 1 and 3, is also the shortest path between vertices 2 and 3. A path is overestimated at first, distance from each point to starting vertex is calculated and shortest weighted one is chosen. Then we visit each node's neighbours to find the shortest sub path to those neighbours and so on.

2.3.3. A* Algorithm

This algorithm is normally used in games where there are multiple hindrances in path of the user. It's a smart algorithm that introduces a heuristic into a regular graph-search algorithm, by planning ahead at each step so a more optimal decision is made. It's an extension of Dijkstra's algorithm and makes use of attributes of breadth first search BFS.

A* algorithm given a starting point, considers all adjacent nodes to it and makes a list of cost (distance or time to each node). Once the list has been populated, inaccessible nodes are removed and the cell with the lowest cost is picked. This process is done recursively until the shortest path to target node has been found. In context of this paper, Navmesh routing, a library in Unity software, makes use of A* algorithm inherently.

2.4. SCALABILITY FACTORS

Selection of the most appropriate information inter-connection method can be considered key to a reliable smart warehouse system. Method is selected based on several factors such as:

- **Size of Wearhouse**: Some solutions are only suitable for small scale warehouses. as cost in implementing them increases exponentially with the size of the establishment. For instance, it could be very expensive to place LED lights over an extensive area.
- **Variety of items**: Variety and total count of warehouse content, each with its own stock keeping unit.
- **Cost**: Both one time implementation cost and maintenance cost of everyday wear and tear

2.5. LIMITATIONS

2.5.1. Technical Limitations

Wearhouse management usually demands long hours from its employees. Frequent use of Head Mounted devices and Smart Glasses can cause eye strain and vision disabilities. Therefore, some of the operators in warehouses could be reluctant to wearing these devices for long hours. Moreover, another problem associated with Head Mounted or Sound based devices is that it demands long and consistent battery life. Otherwise, the operator would have to carry portable batteries, which could be an added concern that could reduce the demand of the product significantly. (Marie-Helene Stoltz, 2017)

2.5.2. Systematic Limitations

The very first issue of implementing AR in warehouses is the combined organizational reluctance to change. Most companies have already adapted to the traditional paper-based pick lists and refuse to implement new processes in their work area.

Further, privacy is a prime concern of both workers and managers. They are reluctant to engage in AR because AR-based services require constant camera surveillance and an internet connection with the online database.

Lastly, Pakistan as a country has no standardization of warehouse design. That is, most warehouses don't have any zoning or proper shelfing system and items are just stacked on top of one another with no order. This can cause an issue for digital management using AR services, as AR requires proper labelling of zones to items, for establishing a proper indoor navigation system.

2.6. INDUSTRIALLY USAGE EXAMPLES

2.6.1. DHL

One of the world's leading logistics and courier company can be considered a pioneer in introducing Augmented reality in warehouses at industrial scale. First pilot tested in 2015, followed by successful and promising results led them to setting a new standard in order picking for the supply chain industry.

DHL essentially uses Vision Picking and makes use of smart glasses that provide visual displays of order packing instructions along with directional instructions as to where the items are located and where they must be placed.

2.6.2. KPMG

One of the Big 4's of global auditing companies implemented AR technologies and have slowly started bringing them into practice.

Typically, KPMG's auditors had to visit client's warehouse for inventory counting. With the introduction of smart glasses and augmented reality the technology has allowed off site auditors to view and interact with the inventory in real time. This enabled audit teams to observe inventory activities without having to travel to warehouses, thus saving travel costs for their companies.

3. METHODOLOGY

3.1. PROJECT OBJECTIVES

The main goal of our product is to minimize the errors caused by manual input and to create a system that can be updated in real time. Along with this, we hope to optimize the working conditions of the employees, increase time efficiency, and reduce workforce labour and setbacks due to human oversight.

To combat these problems, our product will be curated and designed to aid warehouses with their inventory, handling, and storage of the items. A structured and organized description of the shelves and inventory will be uploaded in an online database that can be visualized in the form of a virtual map. Information regarding the precise registered location of each catalogued item shall be done by super imposing the image data onto the user's field of view, making it easier for the worker to understand his tasks.

A detailed plan of the features to be added that will enhance the performance of our product is as follows:

3.1.1. Product Visualization and Identification

The workforce shall be capable of accessing and managing stocks using AR technology. Detailed information of any product or finding the best route to it shall be displayed right in front of the operator at their ease. This shall help them to visualize what is demanded of them, enabling them to complete tasks more efficiently and accurately with fewer delays.

One of the biggest advantages of Augmented Reality is that it creates unique digital experiences that is the perfect blend of both the digital and physical worlds. It presents information in neatly summarized digital snippets. This in turn, spares the worker from having to process too much information to arrive at a conclusion. This allows for quick decision making without having cognitive overload.

3.1.2. Improved Pick Speed

In warehousing, as order picking entails for 60% of total expenditure, it is of utmost importance to propose an optimized solution for a streamlined retrieval system. Tracking of items is facilitated as Augmented Reality provides precise information regarding the mobility, location, and situational awareness of smart objects. The objective is to enable a picking algorithm which is fast, error-free, and user-friendly while guiding the human operator.

3.1.3. Improved Inventory Visibility

Warehouse managers are bestowed with the duty to manage and fulfil incoming orders. Therefore, it is expected of them to have a streamlined work-process in the warehouse. Keeping that in hindsight, many companies have embraced AR in all their warehouse operations, from its planning phase to distribution phase, to allow for maximum efficiency.

AR enables for increased visual control for monitoring of stocks and keeping check of units sold and those remaining. Efficiency increases by folds, and costs are minimized by reducing likelihood of error from data inconsistency.

AR can provide deeper insights and greater control over what's on the shelves, what's in process of shipping, and trending customer demands. Developing proper control and visibility over the inventory is a game changer, as the manager can effortlessly extract information regarding any product using an online database. This allows for minimal to zero chance of data inconsistency to occur.

3.1.4. Process Logging and Quality Monitoring

This technology can allow the warehouse manager to monitor the picker's or worker's condition and performance. This facilitates in staff recruitment, employee compensation and benefit allotment upon merit, and designating work tasks to each employee. The main objective is to maximize productivity of the entire corporation by optimizing effectiveness of its employees.

Manager can quickly assess the productivity of any employee. The worker can also check their own status and designation in the system.

3.1.5. Cost Efficiency

A huge advantage that comes alongside this technology is that it does not need any special hardware or software to savour the experience. Mainstream smartphones and mobile apps are sufficient to experience Augmented Reality. Which is the route we've decided to take in this case.

Mobile phones have become a necessary part of our lives, it is a commodity that is owned by a majority of the people. Our decision to make use of mobile phones as a medium for AR reels down the cost and resources that would be used to create an independent device and then distributing it among the employees. To put it shortly, it is a less expensive option.

Along with it being cost effective, it also helps us save up on time, resources and money that will be needed to distribute an added equipment to the employees. Creating an AR designed for mobile phones eliminates the burden of carrying an extra piece of work equipment all day long. And the portability of the phones is an added bonus to the already favourable equation of it being a light weight and cost-effective solution.

Also, with the internet service at hand and the aided features now available across most mobile devices, many of the phones can be considered minicomputers. Along with the boom of social media, many businesses have also deemed mobile phones as a part of their workforce. Due to these reasons, mobile phones have been modified to sustain longer periods of active time and thus have a longer battery life, which in turn benefits us in our end goal.

3.2. USER CLASSES AND CHARACTERISTICS

System shall constitute of three user modes, each with their own dashboard tailored to their individual needs.

3.2.1. Manager Mode

Intended for the Manager of the warehouse. It shall provide the user with a bird eye view of all the operations currently taking place in the warehouse. This includes management and control over workers, orders, and stock.

3.2.2. Picker Mode

Intended for the Workers employed in the warehouse assigned for picking tasks. User shall be assigned Pick operations automatically and virtual aid shall also be rendered making use of AR technology.

3.2.3. Packager Mode

Intended for the Workers employed in the warehouse for compiling orders into packages. User shall be assigned to package an order automatically when all items of that order have been picked. Virtual aid shall be provided to ease the process and ensure correct packaging.

3.3. OPERATING ENVIRONMENT

The hardware, software and technology used should have following specifications:

- Ability to connect to the Wi-Fi or mobile network
- Ability to exchange data over the network
- Functional on Android 7 or greater
- Ability to use camera, microphone, and other services of mobile

3.4. DESIGN AND IMPLEMENTATION CONSTRAINTS

For indoor navigation to take place, GPS tracking cannot be utilized, as that technology only gives an accuracy within 4.9 m (16 ft), which proves to be deficient for accurate item picking. We replaced GPS navigation with position and rotation tracking using the phones' sensors.

To implement this, developers will be required to make at least 2 visits to the facility to take an inventory check and map the warehouse, down to its exact dimensions so as to update their virtual map, that is to be fed into the system for indoor tracking.

While using the phone's sensors is more cost efficient as compared to AR glasses, the gyroscope and accelerometer of the mobile aren't so fine tuned for accuracy. This may cause a drift error in tracking of up to 2 meters.

Another challenge to implementing AR technology in warehouses is the resistance to change from organizations. Many companies have already adopted paper-based pick lists and are hesitant to adopt new processes in their work areas.

Furthermore, privacy is a significant concern for both workers and managers. They are reluctant to use AR-based services due to the need for constant camera surveillance and an internet connection to access the online database.

In Pakistan, there is a lack of standardization in warehouse design. Most warehouses do not have a zoning or shelving system in place, resulting in items being stacked haphazardly with no organization. This presents a challenge for implementing digital management systems that rely on augmented reality (AR) technology, as proper labelling and zoning of items is required to establish an effective indoor navigation system. So, the development team shall have to individually scour and identify item details to feed into the system.

3.5. ASSUMPTIONS AND DEPENDENCIES

- Network and data availability on worker's phone
- Better connection for exchanging data over network
- Availability of mobile services like camera, etc.
- Permission to install visual markers throughout warehouse is granted
- Accurate mapping of warehouse area and dimensions is conducted

3.6. INTERFACES

3.6.1. Hardware Interfaces

As described in section 3.3, the application is designed for and will work on any smartphone with Android Version 7 or greater. Further, it shall require the phone to have camera and internet-based services.

3.6.2. Software Interfaces

- The system shall work for android based devices with version 7 or higher.
- The system shall communicate with registered external e-commerce services, from where they shall receive orders to be picked and delivered.
- The system can be improved to include communication with external dispatch services to discuss orders' shipping details.

3.6.3. Communications Interfaces

The application will simply make use of Wi-Fi or cellular connections of the smartphone on which its being used. These communications will be required to constantly stay connected to the back-end database.

4. REQUIRMENT SPECIFICATION

4.1. SYSTEM FEATURES

Snap Pick shall essentially be providing the following functions.

- Sign In function for all user types
- Provide Manager with a dashboard that displays sales with respect to Orders
  - Can filter based on date
- Allow manager to monitor Worker details
  - View worker according to their status
  - Clicking on worker shows pop up, that includes further details on their performance
  - Register workers
- Allow manager for Order administration
  - Orders are fetched into database from associated e-commerce website (currently server creates dummy orders for testing purposes)
  - View order details
  - Filter through orders based on date
- Allow Manager to monitor and update stock inventory
  - Check **inventory status**
  - Search through stock based on item name or item ID
  - Filter through stock based on category of item
- Performance reports
  - Displays time taken by pickers to complete retrieval of each pick bucket
  - Zone wise reporting in the form of pie chart to determine hot zones, so the manager can sort workers and items in accordance
  - Show categories and items associated with each zone
- Provide all user types with a profile screen
- About screen showing details about the app
- Guide and aid Picker to orders to be Picked
  - Position tracking using accelerometer and gyroscope readings
- Create and manage **Pick Buckets**

    - Automatically assign Pick Buckets to Picker based on **worker status**
    - Pick Buckets are unique to each zone
    - AR based guidance to required destination
- Allow Packager to view order details, alongside product images of each item on list to ensure correct packaging

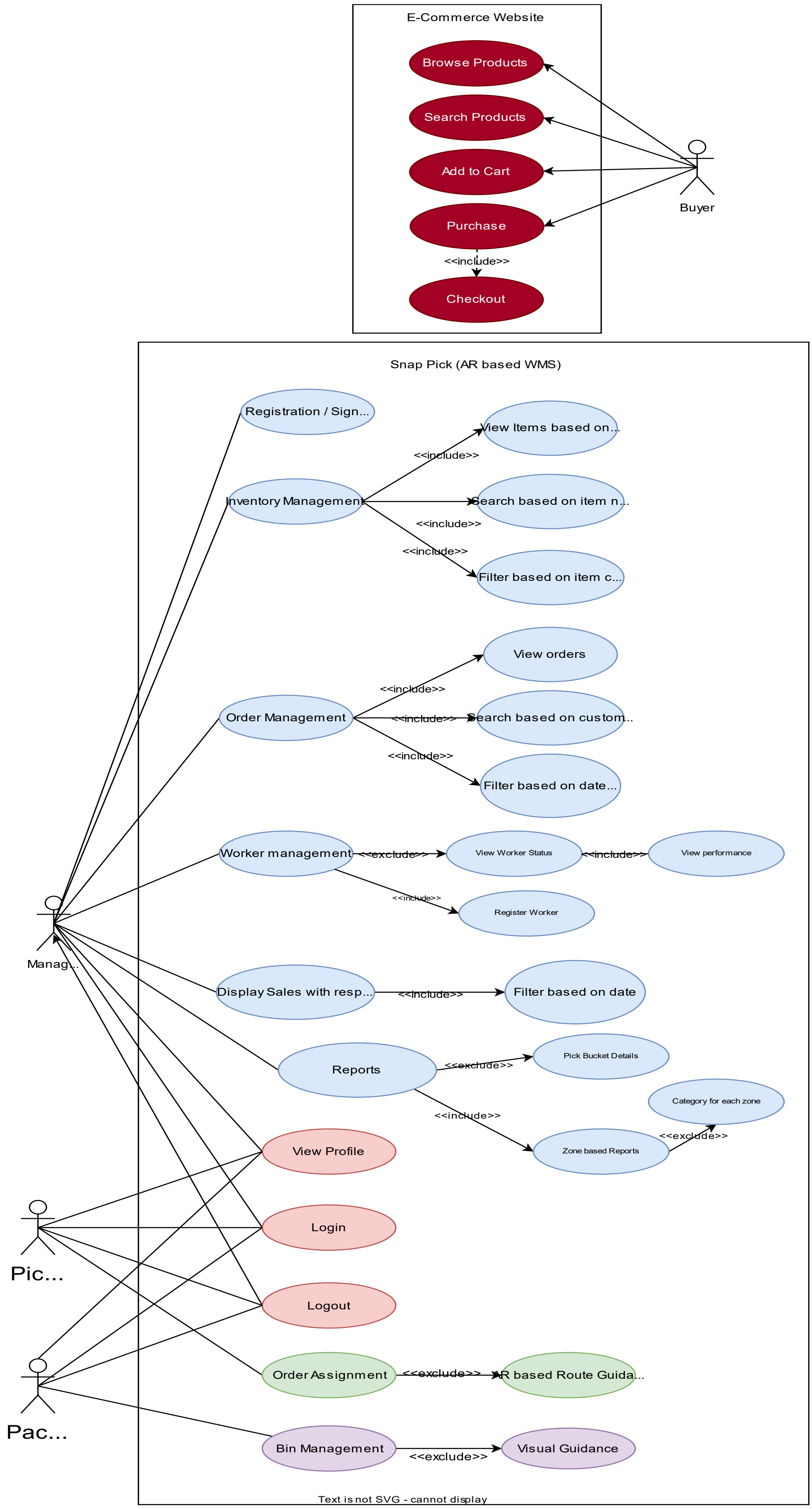

Figure 1: Use Case Diagram

4.2. FUNCTIONAL REQUIREMENTS

In this section, we shall formally be describing functional requirements of the application. We shall be making use of Sequence Diagrams to illustrate the requirement clearly wherever required.

4.2.1. Authorization

This feature shall allow the Manager to Sign up on the application and further register Workers for the same Warehouse. Moreover, both workers and manager have the login feature available to them.

Priority: High

- System shall allow Manager user to register on the application using Email, Password, Name and Warehouse Name.
- System shall verify the email before allowing the Manager to Login into the application.
- Workers shall only be registered by Manager of the Warehouse.
- Workers shall only be able to login using the credentials stored by the Manager.
- System shall change Picker Status from "unavailable" to "available" as soon as the Picker logs into the application.
- On Logout, Picker status is changed to "unavailable."

4.2.2. Interactive and Dynamic Dashboard

This feature is to provide dynamic dashboards with respect to operations being carried out in the Warehouse, to the Manager, Pickers, and Packagers respectively when they log on to the system.

Priority: High

- System shall route Manager, Picker, and Packager to different dashboards upon logging in to the application.
- Manager shall be provided with dynamically updated data for the following:
    - Sales Section
        - Number of Orders Completed
        - Number of Orders Pending
    - List View of all the Orders alongside their details
        - Order ID

    - Customer name
    - Date the order was received on
    - Order status
    - Total amount (in Rupees)
- Manager shall be provided an option to Filter Orders data based on both Date.
- Manager shall be provided with a Bottom Navigation bar to seamlessly browse between Orders Page, Worker Details Page, and Stock Details Page.
- Picker shall be provided with a List View of assigned Pick Buckets to them on their dashboard.
- Packager shall have a view of **Package Bins**, and upon pick process completion of an order, Packager shall be guided by the system in packaging that item from its respective bin.

4.2.3. Order Details Card

This screen is to provide the manager of the warehouse with a detailed view related to all orders that the warehouse has received.

Priority: High

- Order details shall only be available to the Manager of the Warehouse.
- Orders Card shall present the manager with details of all the orders in a tabular manner. These details include:
    - Order Id
    - Date
    - Status
    - Total (in rupees)
- Details of all the orders on the Orders Screen shall change dynamically according to their order status.

4.2.4. Stock Details Page

This screen is to provide the manager of the warehouse with a detailed view and control of items currently present in the warehouse.

Priority: High

- Stock Details Screen shall only be available to the Manager of the Warehouse.

- Stock Details Screen shall present the manager with details of all the products in a tabular manner. These details include:
    - Item Id
    - Item Name
    - Quantity
    - Category
- Stocks screen shall be divided in two major sections, one showing the in-stock items and their details, and the second being the out-of-stock items section.
- Stocks Screen shall provide an option to Filter the data based on categories.
- Details of all the items in Stock shall be updated dynamically as items are picked and packaged.
- Manager can add item details, either manually through a form or via an excel based sheet.
- Search through stock based on item name or item ID

4.2.5. Worker Details Page

This screen is to provide the manager detailed information about all the Workers in the warehouse based on their status.

Priority: High

- Worker Details Screen shall only be available to the Manager of the Warehouse.
- Worker Details Screen shall provide all Worker details in tabular form.
- The screen shall be divided in three major sections, one showing all registered workers, second showing all pickers with their available status and zone, and the third showing all packagers.
- Workers can have any of the following **Worker Status**:
    - Unavailable: Picker isn't logged in
    - Available: Picker is logged in and idle
    - Picking: Picker is during picking operation
- Worker Screen shall present the following fields for all the Workers:
    - Id
    - Name
    - Status
    - **Worker Type**

  - **Zone**

4.2.6. Reports Page

This feature was shows time taken by each pick bucket to be collected and retrieved. Furthermore, zone wise statistics are also available to identify **hot zones**.

Priority: Medium

- Reports screen shall only be available to the Manager of the Warehouse.
- It fetches details of Pick Buckets in tabular form with respective headings:
  - Pick ID
  - Name
  - Time
  - Quantity
- Zone Stats show pie chart with all zones and number of items picked from each zone for identification of hot zones.
- Show categories and items associated with each zone in a tabular form
- Manager can deploy more workers or more space to items present in hot zones.

4.2.7. Pick Bucket Management Algorithm

This feature shall be implemented at the back end for automatically assigning batch picking roles to Pickers based on their status and zone of the items to pick.

Priority: High

- For every new order received, the module shall fetch the zone of each item in the order.
- System shall accumulate items from the same zone into one bucket.
- New bucket is created automatically for items from different zones.
- Pick Bucket is assigned to Workers automatically when either condition is reached, i.e.:
  - Pick Bucket has reached the count for Max Items set by the system.
  - Time t has passed since the Bucket was initially created (currently set to 15 mins for testing)

4.2.8. AR Guidance

This feature makes use of Augmented Reality AR based services to guide the Picker to the specific shelve and aisle of the respective item.

Priority: High

- System shall use the in-app camera for indoor navigation, that is to determine the Picker's physical location using the phone's accelerometer and gyroscope
- On screen digital guidance shall be displayed to Picker for easy navigation.
- System shall use **A* routing algorithm** to find the shortest route to the item.
- System shall dynamically update the worker status when worker starts navigation to "picking"
- System shall dynamically update the worker status when worker reaches start point after picking all items to "available"

4.2.9. Order Collation

After items have been picked, bought to the packaging desk, and placed in their respective Packaging Bins, the Packager collates the order whose every item has been picked.

Priority: Medium

- As soon as all items of an order have the status "to be packaged", the bin with that order is highlighted on screen for the Packager to start compiling.
- Product details alongside an image of the product of all products in order are available so the Packager can cross check and ensure correct item is packaged.
- System shall dynamically update the order status to "complete" when all items from Packaging Bin are packaged.
- All orders with status "pending" are assigned to bins after every t mins (currently set to 15 mins) by the server.
- Orders are assigned following FIFO (first in, first out) according to date of arrival
- Assigned bins are marked red, and free bins are marked green.

4.2.10. UI animations

These include in between animations to ensure smooth and aesthetic flow between different elements of the app.

Priority: Low

- Icons changed from default unity and flutter ones to custom ones.
- Splash screen after opening the app to ensure smooth transition into the app.
- Loading bar animation when items is being fetched from the database.

4.3. NON-FUNCTIONAL REQUIREMENTS

4.3.1. Performance Requirements

- **Scalability**
    - The system should be able to accommodate at least around 50 users at any given time, to run for a small to medium sized warehouse.
- **Speed**
    - The product shall take initial load time depending on internet connection strength which also depends on the media from which the product is run.
    - The performance shall depend upon hardware components of the client/customers.
    - Application must be as lightweight as possible, to accommodate for less efficient devices owned by workers.
    - Application's processing speed should be high so that there's minimal delay to reflect the change in worker status in physical life and the stored data in database.
    - The app shall not consume much cache memory. Even if it does, it must provide a choice to the user to clear app cache manually.

4.3.2. Safety Requirements

- There are several user levels in this system, with Manager having the highest access level, and the Picker and Packager only having access to functions for their current work role.
- Access to the various subsystems will be protected by a user log in screen that requires a username and password. This gives different views and accessible functions of user levels through the system, and suitable dashboard shall be displayed based on chosen user type.
- The feature for registration of new users in the system is only available to Manager user level.
- Maintaining local backup to ensure no information loss is suffered in case. System can be restoring in any case of emergency.

4.3.3. Security Requirements

- **Data Storage**
  - The system shall use secure sockets in all transactions that include any confidential user information.
  - The Login screen shall not display the user's password. It shall always be echoed with special characters representing typed characters.
  - The system's back-end servers shall only be accessible to authenticated administrators (developers).
  - The system's back-end databases shall be encrypted.
- **Privacy**
  - The mobility domain has a privacy sensitive nature, specifically with regards to the location tracking. To create a viable offering for the user we will have to build a simple, transparent system that can be understood and trusted by the people that are using it. To build trust with the users of our system, the system shall make use of the following strategies:
    - Encryption on the database end
    - Non-disclosure agreements (NDA) to legally ensure that certain information will remain confidential. This disclosure policies outlines confidential material, knowledge, or information that the parties don't wish to share.

4.3.4. Software Quality Attributes

- **Reliability & Availability**
  - The system should be able to accommodate at least around 50 users at any given time, to run for a small to medium sized warehouse.
  - All data collected by the system shall be preserved safely and should follow data hiding.
  - The system shall be available to workers during normal warehouse operating hours.
- **Portability**
  - The system shall be made available for any mobile based OS, both Android and iOS.
  - Maintainability

    - Regular updates and maintenance can be expected from the development team to ensure stable functioning.

- **Usability**
    - The application is designed to be user-friendly, relying more on recognition of icons and features rather than recall.
    - The system shall provide a uniform look and feel between all the screens.
    - The system shall provide a digital image for each product in the product catalog.
    - The system shall provide clear visual guidance to worker for easier picking and packaging.
    - The system shall make use of appropriate labelled icons and navbars for easy usage.
- **Reusability**
    - The system being developed is general as of now and can be tailored to match with any specific warehouse, after gathering details of the warehouse's stock and mapping the place into database.
    - The algorithms implemented in the system can be reused for managing pick and package process of any small to medium sized warehouse.
- **Robustness**
    - In case the user's device crashes, their work progress shall be stored both locally and later on, on the database servers to enable recoverability.
- **Accessibility**
    - The system shall provide one handed access for improved mobility of workers.

4.3.5. Business Rules

This system will perform under three users which are Manager, Picker, and Packager. The system is designed in a way where responsibility and privileges are provided only to the Manager, whereas the Picker and Packager only have access to functions for their current work role.

The role of manager is elected in the aim of making their hands free from regular interfering with the system. So, the role is more administrative or monitoring rather than being manual management.

The workers, both Pickers and Packagers, are given with the most frequently used features of the system. Their work status change based on their performance. But the workers aren't provided with any high-level access, and only use the AR guidance features to aid in their picking and packaging processes.

4.4. OTHER REQUIREMENTS

4.4.1. Permissions

The following permissions need to be granted in order to access all the features of the application:

- Camera permission to enable correct marker-based positioning and for scanning SKUs.
- The system uses some of the device's storage to save settings and cache frequently revisited content.
- Network access to send and receive data over the Internet.

4.4.2. Support

The system has all supportive help information available in this document.

4.4.3. Backup & Restore

The system provides a backup and automatic restore facility relating to the online cloud database which back up all warehouse data (with permission) and all the backed-up information can be easily restored later.

5. DESIGN SPECIFICATION

5.1. SYSTEM ARCHITECTURE

Snap Pick uses the **three-tier client-server architecture** which is commonly used for user centric applications. The main advantage of a three-tier architecture is that each layer may be built concurrently by a different developer and can be updated or scaled as necessary without affecting the other levels.

These tiers explained in context of this system would be:

- **Presentation tier:** Presentation tier or User Interface (UI) consists of the Mobile app, the component with which the users will directly interact
- **Data tier**: This includes the Firestore database where all the data will be collated.
- **Logic tier:** This includes processing the business logic of the system and includes components that can directly modify data in the data tier. Here, the server acts as the logic tier, organizing orders and assigning worker status for the employees in the warehouse.

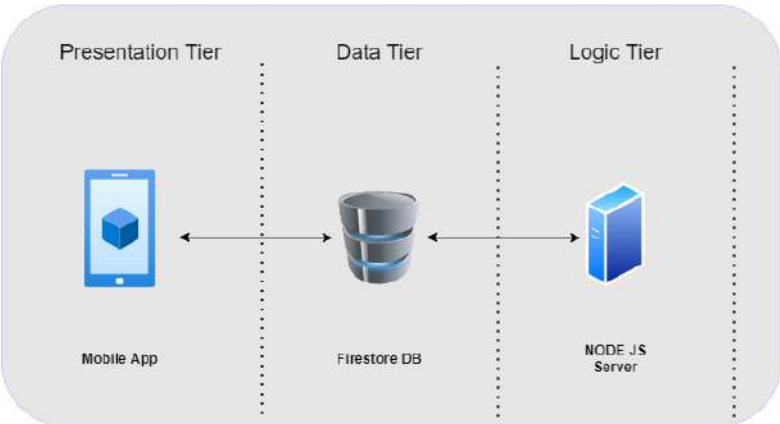

Figure 2: Three Tier Client Server Architecture

5.2. DESIGN VIEWS

A design view represents the architecture of the target system in line with an architecture viewpoint. A viewpoint has two components: the stakeholder issues it defines and the conventions it develops on the view.

Primary objective for the design strategy was to ensure separation of concerns and map practical roles to user roles. This section attempts to provide a conceptual view of the major components of the system and their functionality. Snap Pick's major components include the following design views:

- Manager View
- Picker View
- Package View
- Server View

5.2.1. Manager View

Identification	Manager Module
Type	Module
Purpose	The manager module aims to allow the manager of the warehouse to stay up to date with all the operations in the warehouse.
Subordinates	The module consists of following screens: • Manager Dashboard • Order Details • Worker Details • Stock Details • Register New Worker
Dependencies	The following modules link to this module: • Sign-Up Module • Sign-In Module
Interfaces	Navigation within the Manager module is via Bottom Navigation bar and side drawer.
Resources	Database Access Requirements: The Manager module has access to the entire database
Processing	Processing is done when the data is fetched from the database to show the manager data in a simplified form.
Data	Data is entered when the manager registers a new worker. The following fields are added: • Name

	• CNIC • Email

Context Viewpoint

A class diagram of the manager's view is illustrated to address system services and sub-module interactions and to gain insight into the structure for this view.

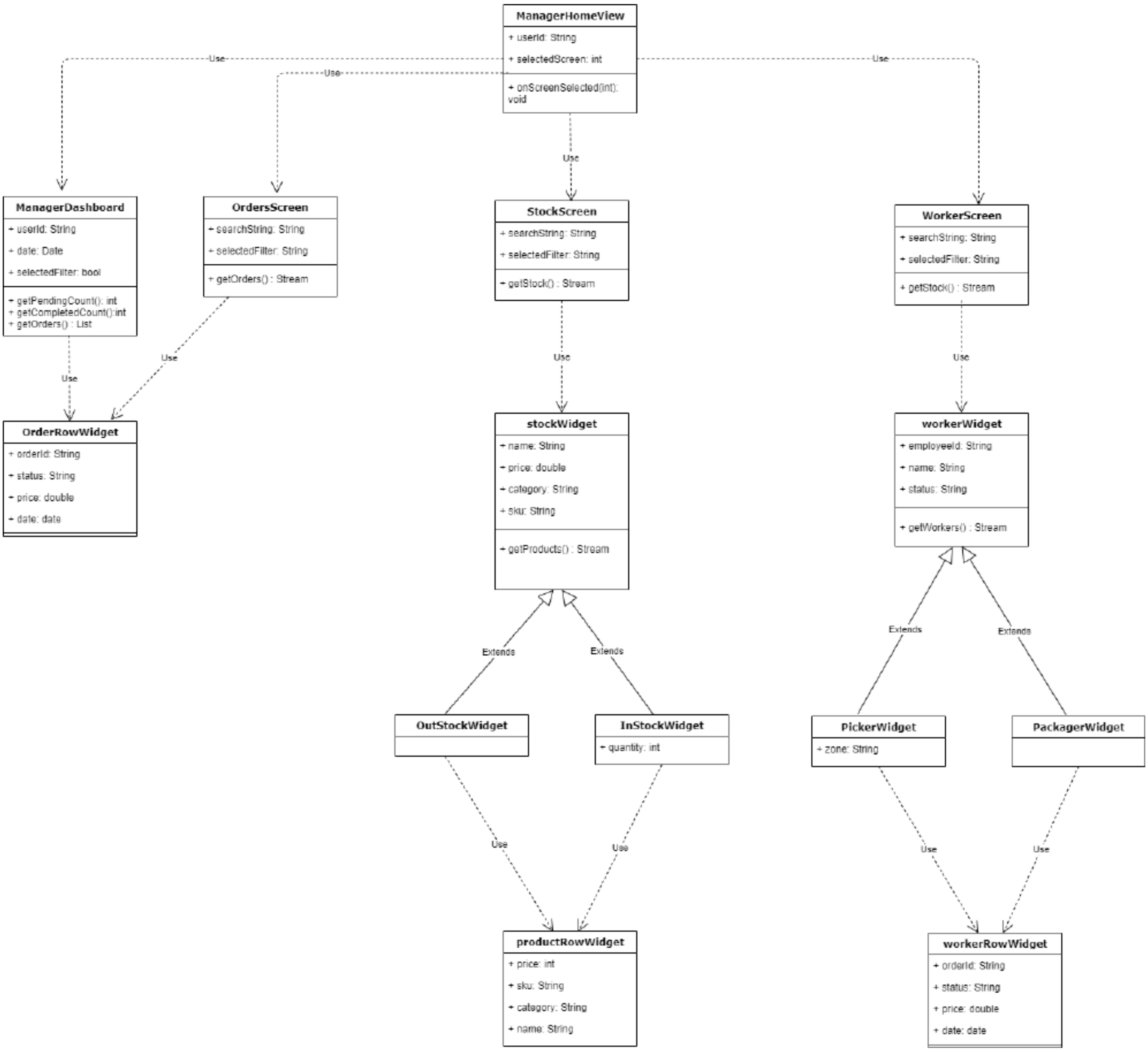

Figure 3: Class Diagram for Manager View

5.2.2. Picker View

Identification	Picker Module
Type	Module
Purpose	The Picker module sole purpose is to aid the picker in picking operations by using Augmented Reality AR services.
Subordinates	This module consists of the following screens: • AR Guidance Screen • Pick Buckets Screen
Dependencies	The following modules link to this module: • Sign In Module • Order Management Module • Pick Bucket Management
Interfaces	The Picker is provided with a tile widget that has button to initiate AR based guidance.
Resources	Database Access Requirements: The Picker module has limited access to the database, pickers can access only the pick buckets in the database.
Processing	Processing is done whenever the user picks and scans item and towards the end when the pick buckets are completed.
Data	The Picker updates the status of a particular order in the database.

Interaction Viewpoint

A sequence diagram of Picker's view is displayed to identify object communication and messaging between different modules in a sequential manner. It displays an example instance of when a picker receives a pick list.

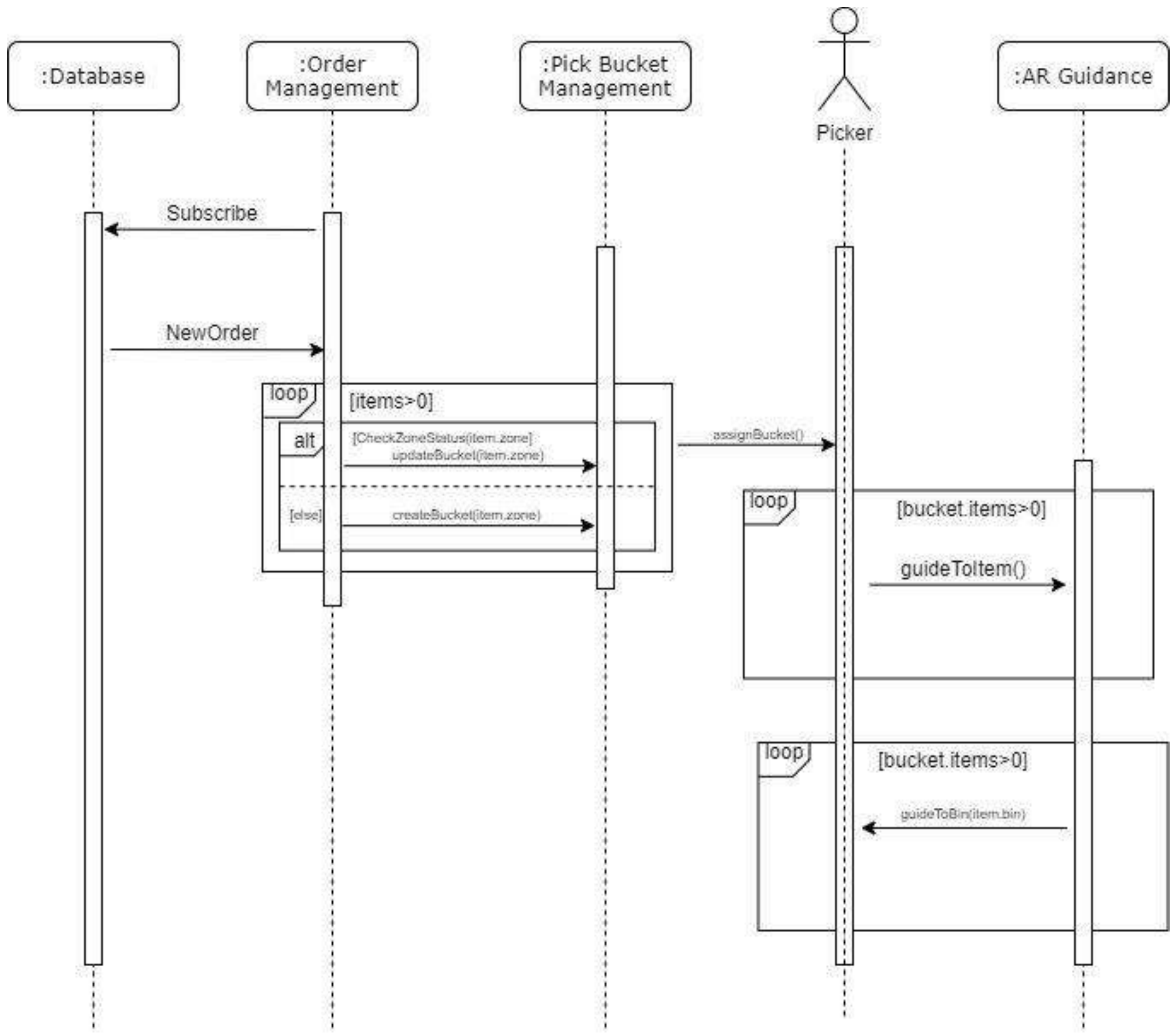

Figure 4: Picker Sequence Diagram

5.2.3. Packager View

Identification	Packager Module
Type	Module
Purpose	Packager Module's sole purpose is to collate the orders at the end of the process and manage Bins status.
Subordinates	The module consists of just the Bins Screen.
Dependencies	The following modules link to this module: • Sign In Module • Bin Management Module • Order Management Module

Interfaces	Packager is provided with a screen showing statuses of all the bins dynamically.
Resources	Database Access Requirements: Packager module has limited access to the database, the packager can only access bins and orders from the database.
Processing	Processing is done whenever the packager marks a bin as complete.
Data	The Picker updates the status in the database for each bin.

<u>Interaction Viewpoint</u>

A sequence diagram of Packager's view is displayed to identify the sequence followed by the packager to collate the orders on his desk into respective bins.

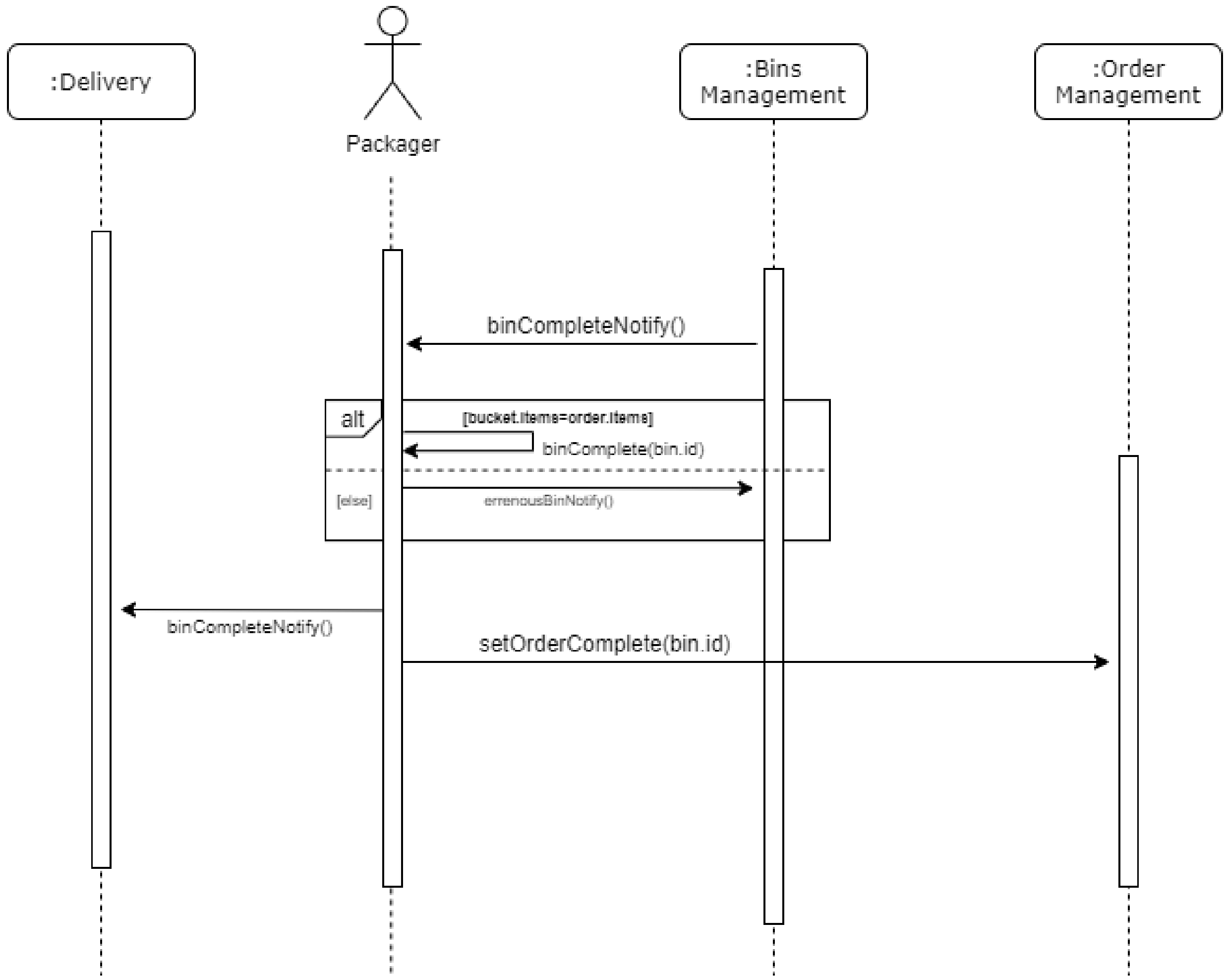

Figure 5: Packager Sequence Diagram

5.2.4. Server View

Identification	External Server
Type	Server
Purpose	Purpose of the server is to process Pick Bucket and Worker assignment algorithms on the server itself, as to reduce local processing.
Subordinates	The module consists of the client database screen.
Dependencies	The following database collections are dependent on the server: • Pick Buckets • Orders
Interfaces	No interface exists for this server, it only involves backend processing.
Resources	The server can make GET API calls to the client's server and can do both POST and GET to Snap Pick's database
Processing	Processing takes place every 15 mins on the server, the server runs the pick bucket and worker assignment algorithm on 15 mins intervals.
Data	Server fetches orders data from the client's database, processes and posts it to the firebase database.

APIs

- **/GetOrders:** API call to fetch all new orders from the client's database.
- **/PostOrders:** API call to post all new orders to snap pick's database.
- **/GetZones:** API call to get zone of each item in the order from the *product* collection.
- **/GetWorkers:** API call to fetch status of all the pickers along with their employee id from employee collection.
- **/PostPickBuckets:** API call to store all the generated pick buckets to Snap Pick's database.

5.3. PROCESS FLOW

The server is scheduled to initiate a GETORDERS API call to run every 15 minutes (this value is dynamic and can be changed at any time). Once new orders are fetched, the server forwards these orders to the database and processes them using the Pick Bucket algorithm.

In the implemented algorithm, the server fetches the zone of each item in the order, using the GetZones API call. Once both the zone and items list are available, the server runs the pick bucket algorithm. The GetWorkers API call is made at Pick Bucket algorithm's end point. With the worker status and pick buckets available, the server then runs another algorithm called the "Worker assignment algorithm" and finally posts the pick buckets with assigned workers to the database using PostPickBuckets API call and returns to idle state.

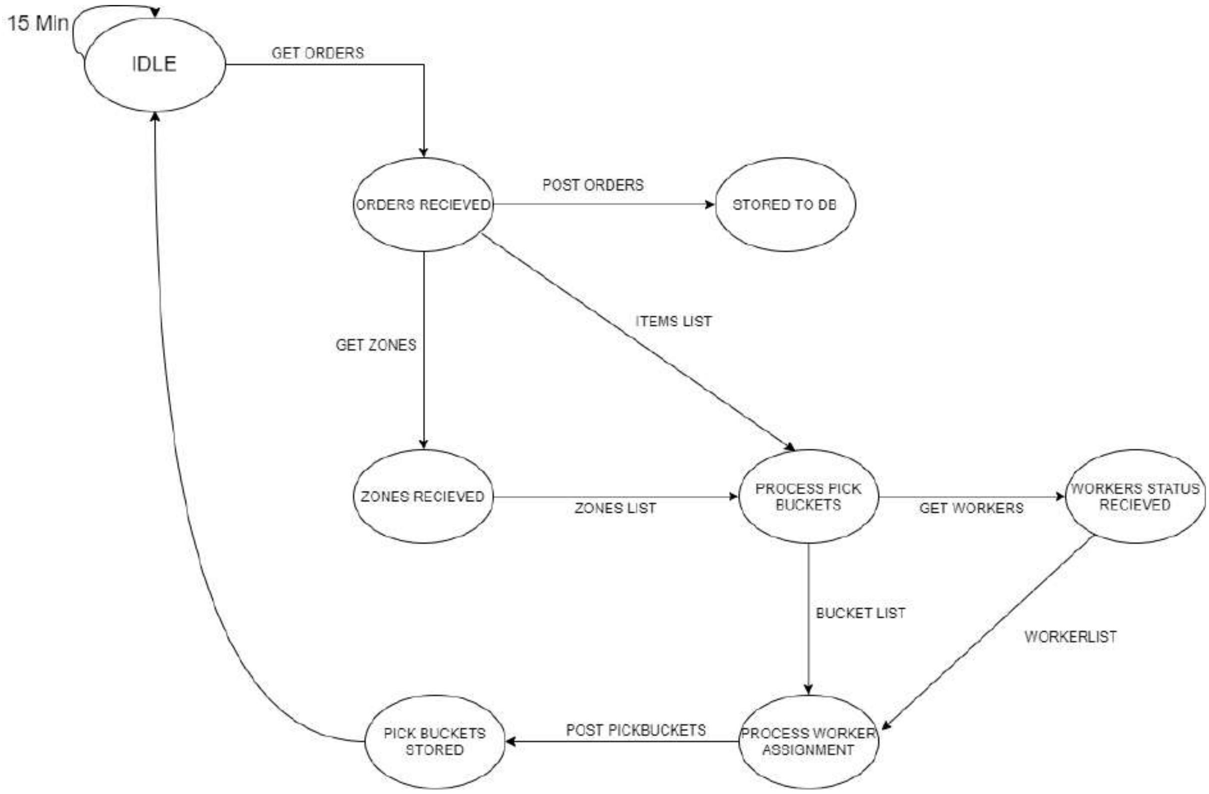

Figure 6: State Diagram

After Picker is assigned order and has fetched all items for a specific pickBucket, they return to the packager's desk. The packager then compiled all items for an order and marks the order ready for shipping. All these process details are being shown to the manager.

5.4. DATA DESIGN

5.4.1. Database

The database chosen for this system is the no-SQL Firebase, due to its high compatibility with Flutter framework.

In firebase, data is stored as collections and documents. Each collection consists of documents, and each document has certain fields.

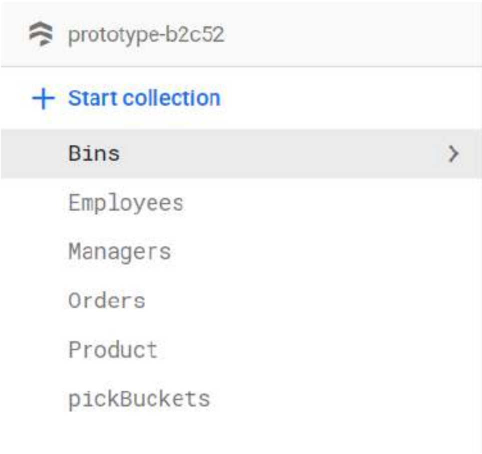

Figure 7: Database Collections

Collections list

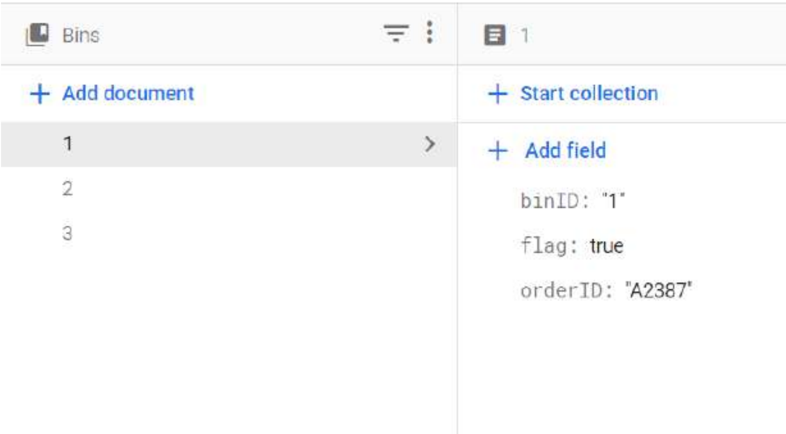

Figure 8: Bins Collection

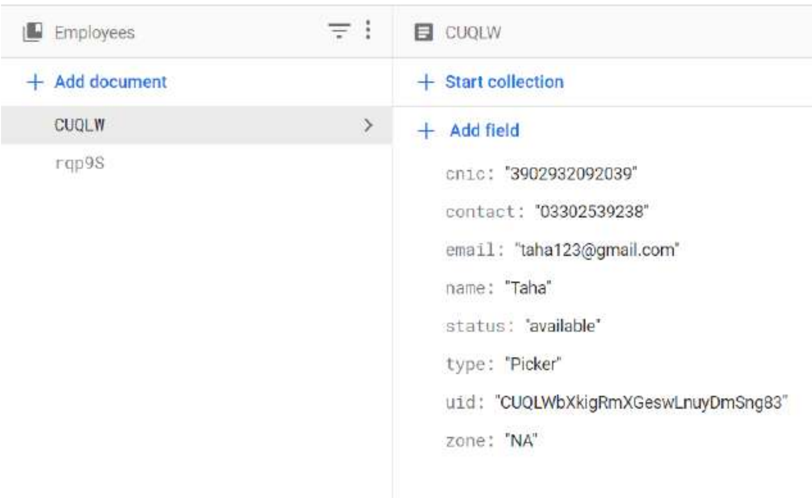

Figure 9: Employees Collection

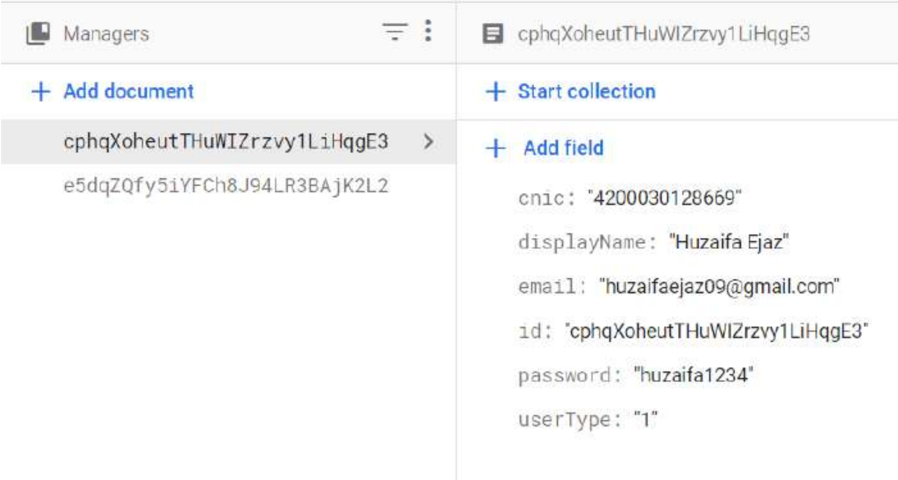

Figure 10: Managers Collection

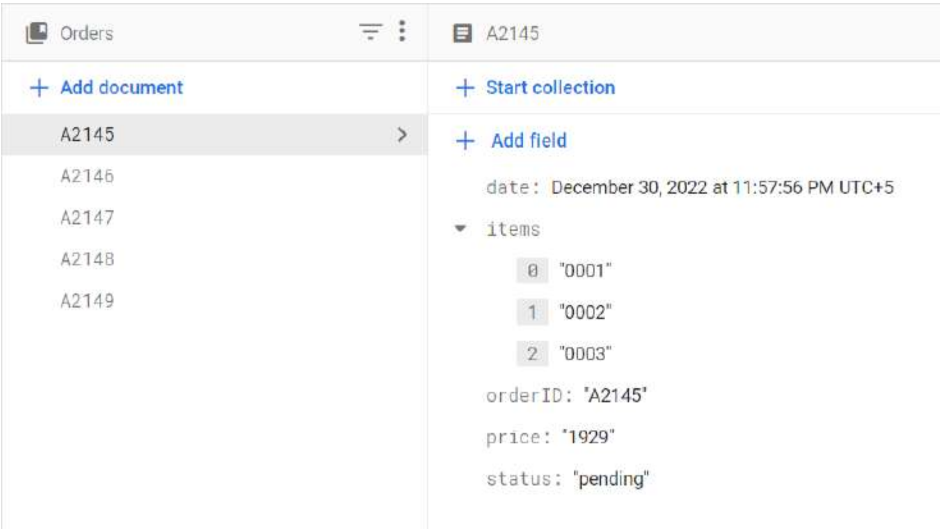

Figure 11: Orders Collection

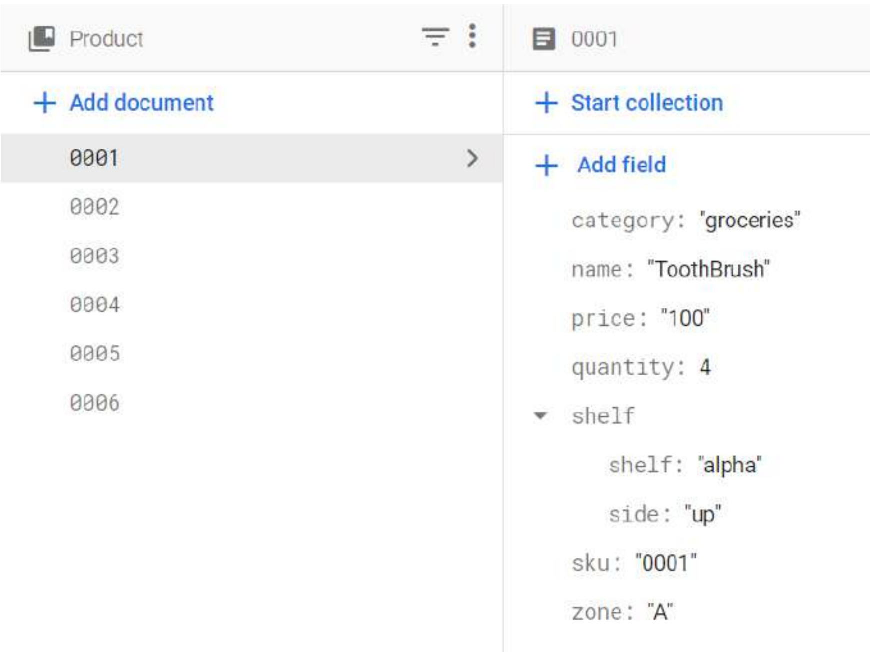

Figure 12: Products Collection

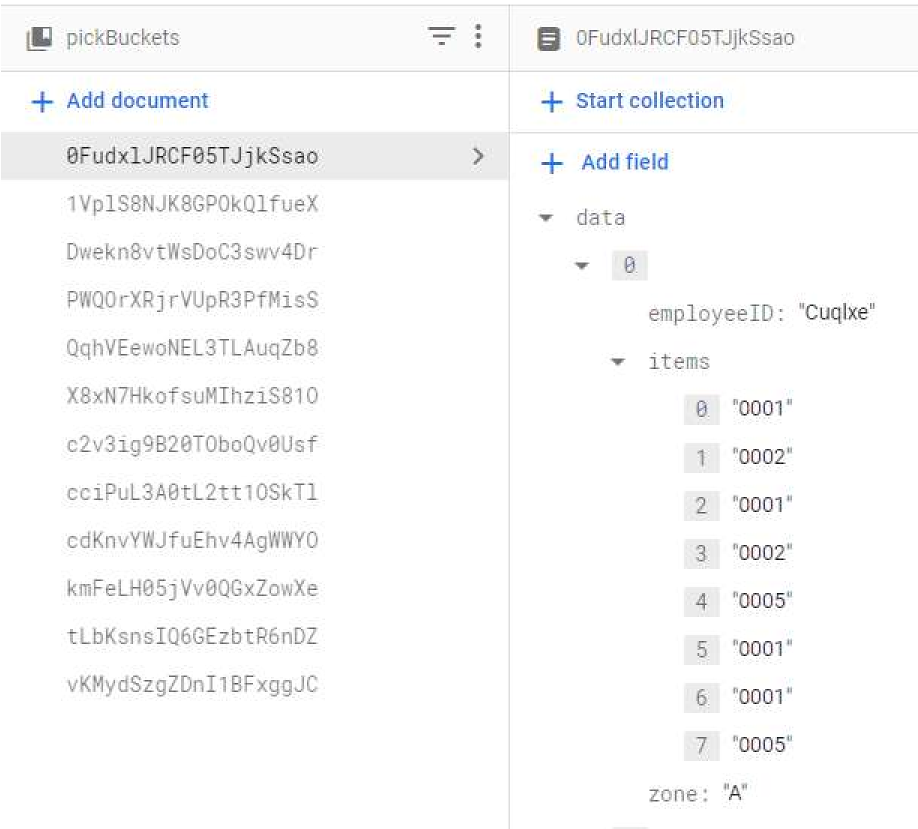

Figure 13: Pick Buckets Collection

5.4.2. Entity Relationship Diagram

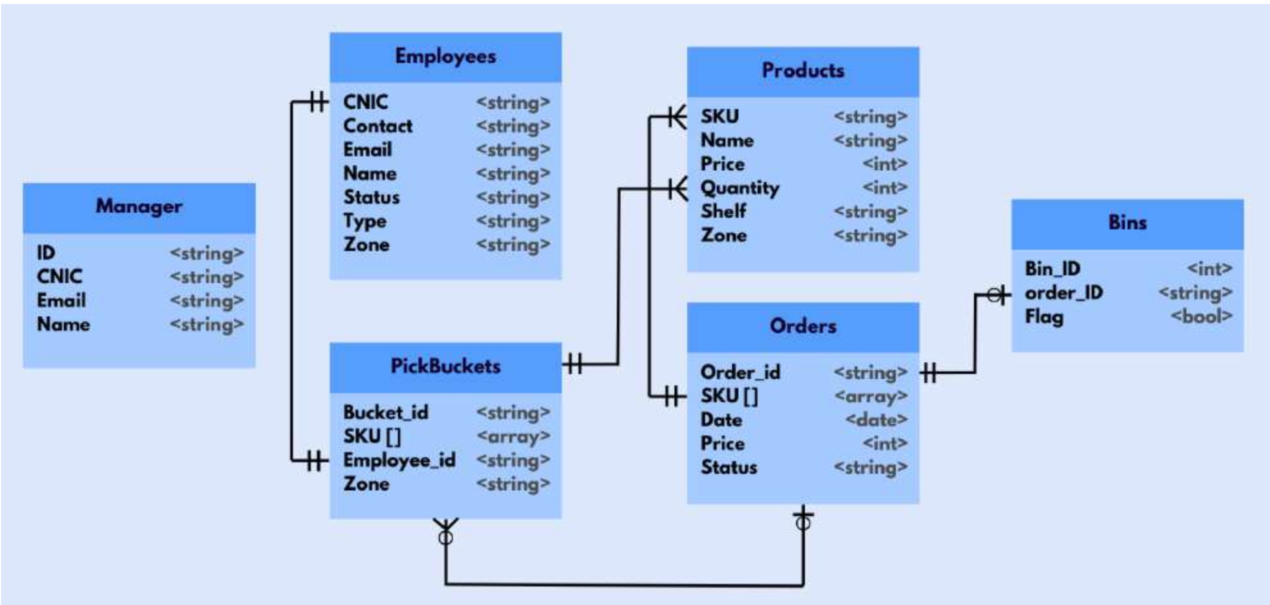

Figure 14: Entity Relationship Diagram

5.4.3. Data Dictionary

Manager				
Field Name	**Data Type**	**Field Length**	**Constraint**	**Description**
ID	String	Dynamic	Not null	Manager ID allotted automatically
CNIC	String	13	Not null	Manager's CNIC number
Email	String	Dynamic	Not null	Email to login with
Name	String	Dynamic	-	Warehouse Manager's name

Employees				
Field Name	**Data Type**	**Field Length**	**Constraint**	**Description**
CNIC	String	13	Not null	Worker's CNIC for security reasons
Email	String	Dynamic	Not null	Login email
Contact	String	Dynamic	-	Phone number for security reasons
Name	String	Dynamic	-	Worker's name
Status	String	Dynamic	Enum	Available, Unavailable, Picking, Returning, Packaging
Type	String	Dynamic	Enum	Temporary or Permanent
Zone	String	1	Enum	Choose from available zones in the warehouse

PickBuckets				
Field Name	**Data Type**	**Field Length**	**Constraint**	**Description**
Bucket_ID	String	Dynamic	Not null	Bucket ID allotted automatically
SKU	Array	4	Not null	SKU for each product in the pick bucket

Employee_id	String	13	Not null	Worker's CNIC
Zone	String	1	Enum	Warehouse zone or location for current pick list

Products				
Field Name	**Data Type**	**Field Length**	**Constraint**	**Description**
SKU	String	4	Not null	Distinct SKU of each product or item
Name	String	13	Not null	Product Name for reference
Price	Integer	Dynamic	Not zero or null	Product Price to calculate sales
Quantity	Integer	Dynamic	Not null	Product quantity to evaluate availability
Zone	String	1	Enum	Warehouse zone where the product is located
Shelf	String	Dynamic	-	Exact location and aisle of the product inside zone

Bins				
Field Name	**Data Type**	**Field Length**	**Constraint**	**Description**
Bin_ID	Integer	2	Not null	Bin ID for each physical bin
Order_ID	String	Dynamic	-	ID of the order allocated to bin
Flag	Boolean	1	Not null	Signifies whether the bin is free or occupied

5.5. DESIGN DECISIONS AND TRADE-OFFS

5.5.1 Enhanced User Experience and Functionality

This design decision is a trade-off between a user-friendly interface and functionality. By focusing on the picker and packager's specific roles, the software's user interface has been made simpler and easier to use. However, this has resulted in missing out on additional functionality which could have been added to the application's interface.

5.5.2 Server processing and complexity

This design chooses to process two of the core algorithms of the system on the server rather than the mobile device itself or local device. This has resulted in a slightly complex architecture that offers more features but it in longer run this has made maintainability of the system slightly more difficult.

5.5.3 Compatibility with Client's Legacy System

The system was designed in a manner that it could be integrated with client's legacy systems through API calls, but this reliance on obtaining information related to orders and products from client's system has limited the system's ability to utilize newer features and technologies.

5.6. RELATIONSHIP TO EXTERNAL PRODUCTS

5.6.1 Dependency Management

All the external libraries used in the system were thoroughly tested with the given use case based on research, it was ensured that the latest versions were being used at the time of deployment. The server is also under continuous integration, any updates in any of the libraries by the developers will instantly reflect in the deployed version.

5.6.2 API Integration

APIs are integrated with the server as means to act a gateway with external databases and product. Given the use case of the system, APIs are integrated to communicate with customer's database effectively within fixed parameters.

6. TESTING

6.1. SYSTEM TESTING

Primarily system testing was conducted to ensure overall quality, reliability, and functionality of the software, which comprises of two mobile apps developed using Flutter and Unity, and a Server developed using Node.js and deployed on Digital Ocean. In this section, tested scenarios are presented, and the performance observed across the system components is listed down. This is to validate the expected behaviour between the components.

Testing was conducted individually on all 3 major components and finally integration testing was conducted.

6.2. FUNCTIONAL TESTING

6.2.1. Flutter Mobile App Functional Testing

Functional testing of the Flutter App was done using the following steps.

- ***Unit tests*** were conducted on specific functions and classes in isolation to test their logical accuracy.

  Tools/Packages used – Flutter Test Package

- Once unit tests corresponding to a widget had passed, ***widget testing*** was conducting with the following objectives:
  - Ensuring all components within a widget are rendered accurately
  - Ensuring widget interaction as per requirements and response to interactions. Scrolling, finding particular components, and tapping were tested during widget testing.

  Tools/Packages used – Flutter test Package, Manual Testing

- ***Integration testing*** was conducted with different user flows, to ensure proper working of Widgets while interaction. Widgets were tested with different user flows.

  Some of the examples include.

- Ensuring Login flows with correct and incorrect credentials and verifying accurate responses were made based on the event that had occurred.
- Mock users were created to test Firebase authentication
- Widgets with drop downs were tested with varying user flows to ensure they respond appropriately in different user flows.

Tools/Packages used – Flutter integration_tests package, mock_firebase

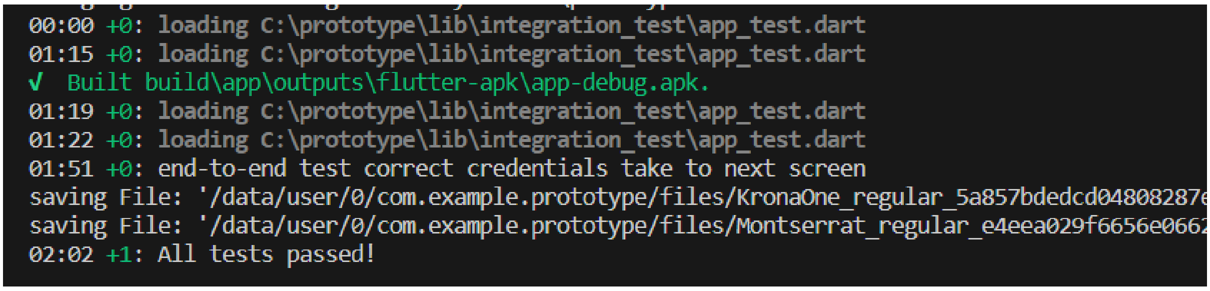

Figure 15: Test to ensure correct credentials log in the user

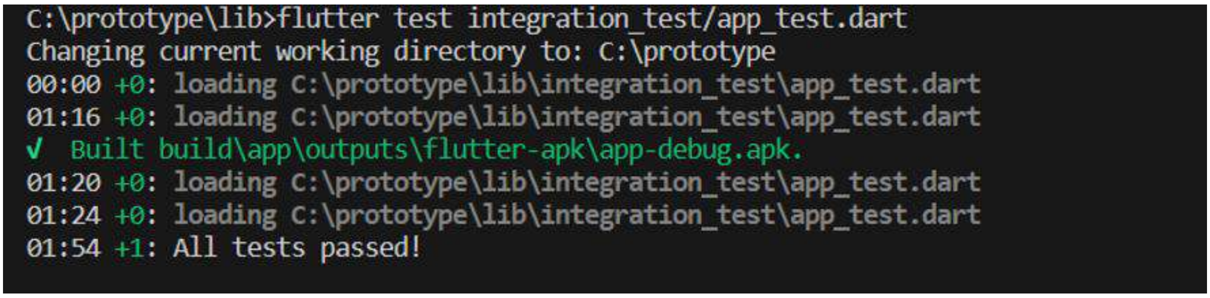

Figure 16: Test to ensure wrong credentials generate an error message

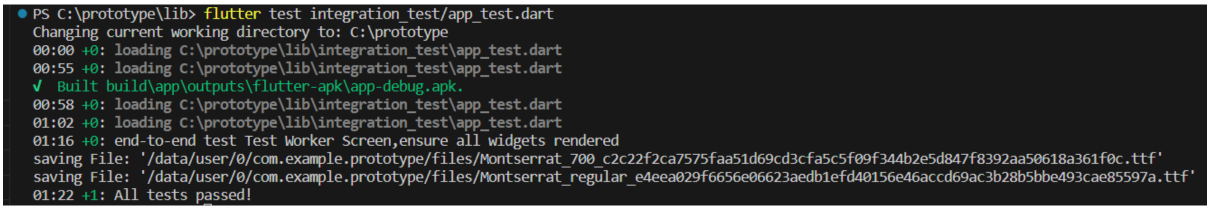

Figure 17: Test to ensure all widgets on Worker Screen render properly

Figure 18: Test to ensure drop down Filters work as required

```
C:\prototype\lib>flutter test integration_test/app_test.dart
Changing current working directory to: C:\prototype
00:00 +0: loading C:\prototype\lib\integration_test\app_test.dart
01:11 +0: loading C:\prototype\lib\integration_test\app_test.dart
√  Built build\app\outputs\flutter-apk\app-debug.apk.
01:15 +0: loading C:\prototype\lib\integration_test\app_test.dart
01:19 +0: loading C:\prototype\lib\integration_test\app_test.dart
01:41 +0: end-to-end test ManagerHomeView displays correct content
0
01:45 +1: All tests passed!
```

Figure 19: Test to ensure ManagerHomeView widgets render properly

6.2.2. Node JS Server Functional Testing

Node JS server is used in the system for running required algorithms online. Server testing included load and stress testing after deployment on Digital Ocean.

- All the API's used were tested using Postman with varying inputs to perform load and stress testing.
- Performance of each algorithm under varying inputs were tested individually.
- Lastly, the server and algorithm were tested when integrated with both the mobile apps and performance was then observed with API calls being made through the Flutter app instead of Postman.

Tools/Packages used – Postman, Manual Testing

6.2.3. Unity Mobile App Testing

Since the Unity app's sole purpose was Augmented-Reality based navigation in the field, extensive testing was done physically in the field itself.

- Initially, testing was done with hard coded navigation coordinates to ensure navigation was working properly.
- The app was handed to random people present on field to take in their experience response and changes based on their inputs were made.

6.3. NON-FUNCTIONAL TESTING

Flutter app was tested using Firebase Test Labs. The tool helps to perform integration testing within the app across different devices in both portrait and landscape orientation. Key results were as follows:

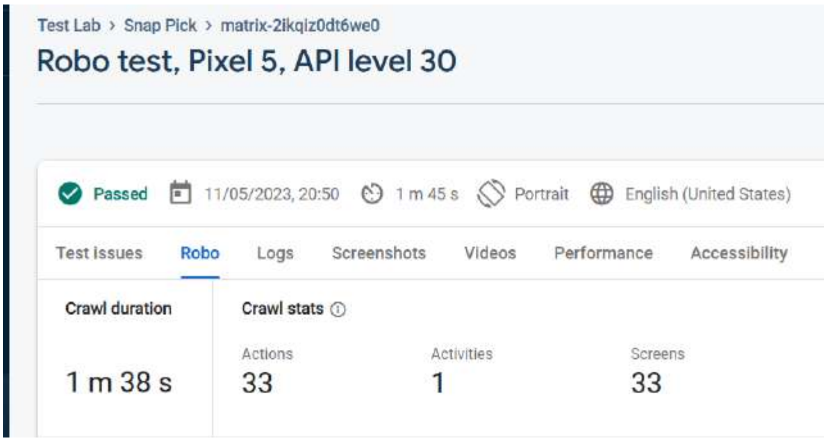

Figure 20: Firebase Test Labs results overview

6.3.1 Performance Testing

Firebase Test labs provide an extensive detailed performance report based on several parameters that are critical for excellent user experience.

1. **Start-up Time and Time for Full display.**

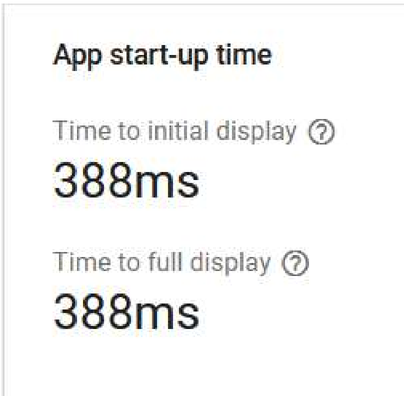

Figure 21: Flutter app TTID and TTFD

Industry Standard for TTID and TTFD is less than 2 seconds. Times recorded for Snap Pick were found to be under the 2 seconds bracket for both TTID and TTFD.

2. **CPU (Percent), Graphics (fps) and Memory (KiB)**

Firebase test labs also provides detailed graphs for these key parameters to ensure that the application is not resource intensive for the Mobile Phone being used.

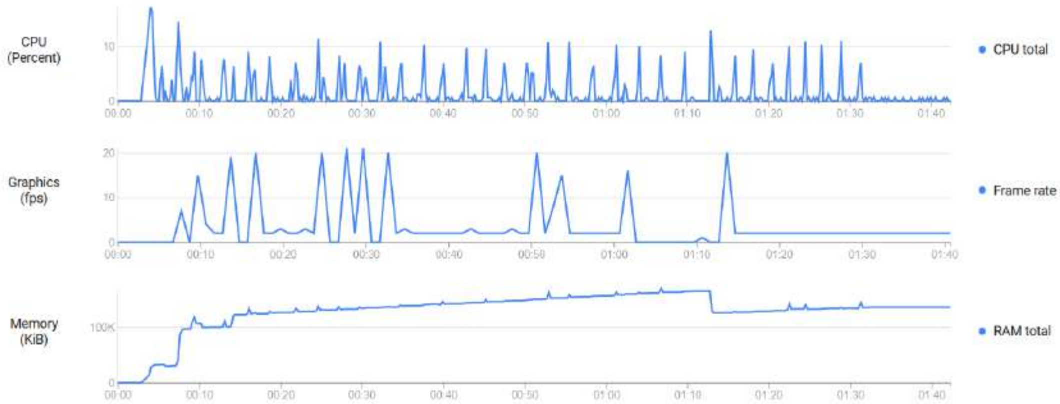

Figure 22: Resource consumption graph for Flutter App

All 3 resources used by the application were found to be within the industry standard.

7. DEPLOYMENT AND INTEGRATION

Deployment of this system primarily releasing signed APK versions of both the mobile apps and deploying the Node JS server on the cloud. Signed APK versions are released, the applications are not deployed on the play store since this is intended to be a bespoke system.

7.1. DEPLOYMENT

Digital Ocean droplets virtual machine was used to deploy the Node JS server. A monthly subscription of a virtual machine with a single core of CPU and 50GB off SSD storage is subscribed for the system. The is scalable at any time based on the load on the server.

7.2. INTEGRATION

The system was primarily integrated through API's, as discussed in the architecture section each dedicated component of the system has a single responsibility and is linked to other components by means of API while the Firebase database being the central point to all of the data integration.

8. USER INTERFACE AND EXPERIENCE

8.1. MANAGER SCREENS

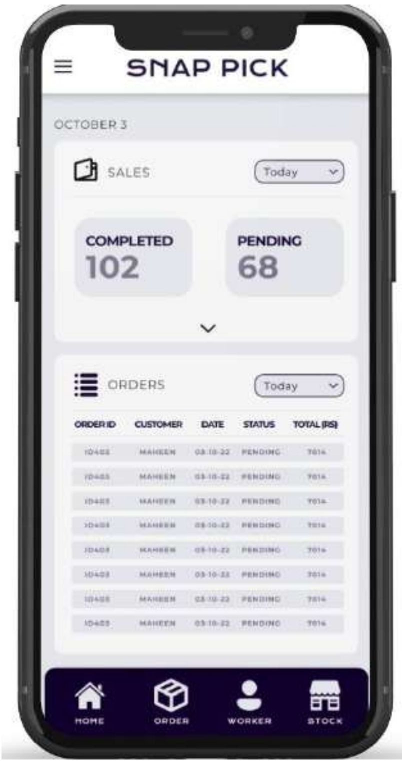

Figure 23: Manager Dashboard

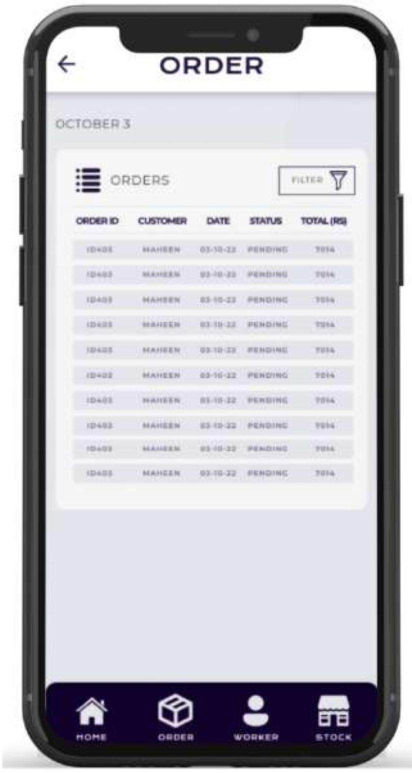

Figure 24: Orders Screen

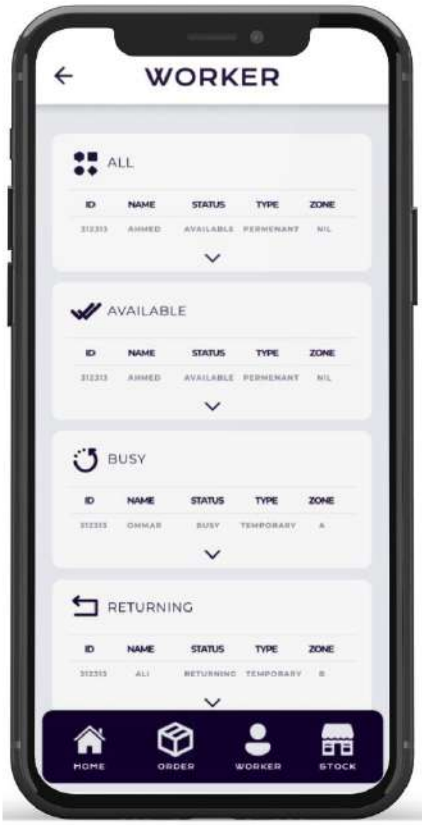

Figure 25: Workers Screen

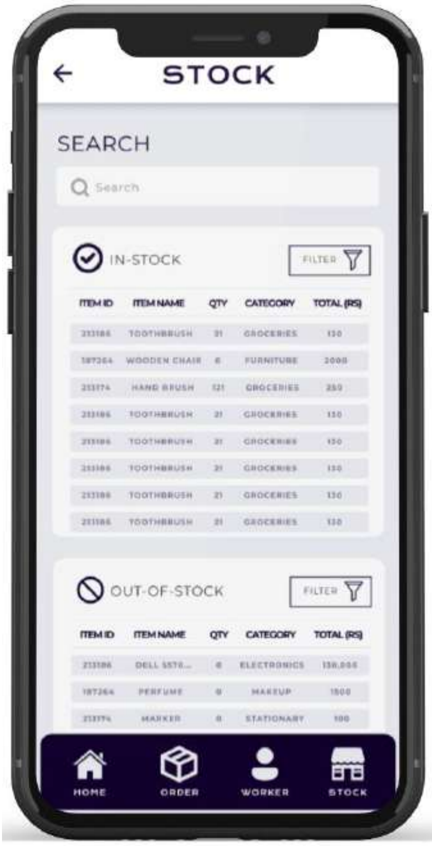

Figure 26: Stocks Screen

Figure 27: Reports Screen

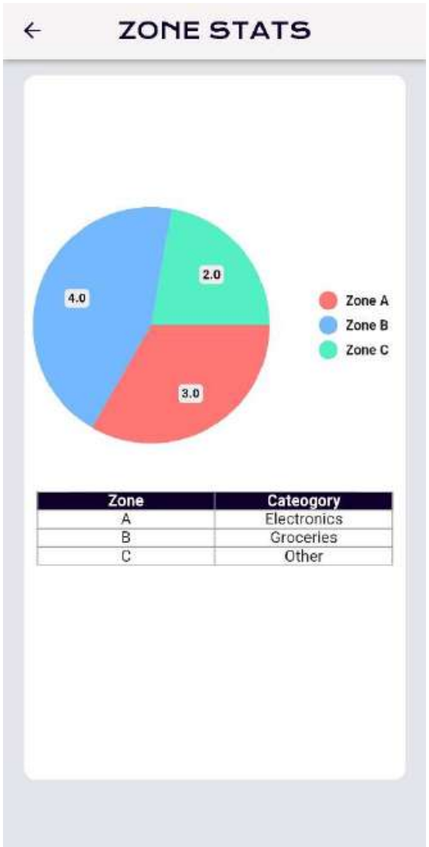

Figure 28: Zone Stats

8.2. PICKER SCREENS

Figure 29: Picker Dashboard

Figure 30: Worker Profile Screen

Figure 31: Picker AR Screen

8.3. PACKAGER SCREENS

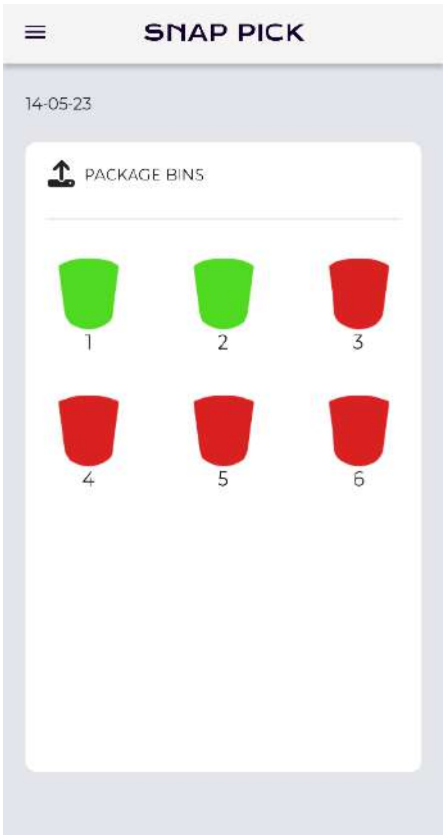

Figure 32: Packager Dashboard

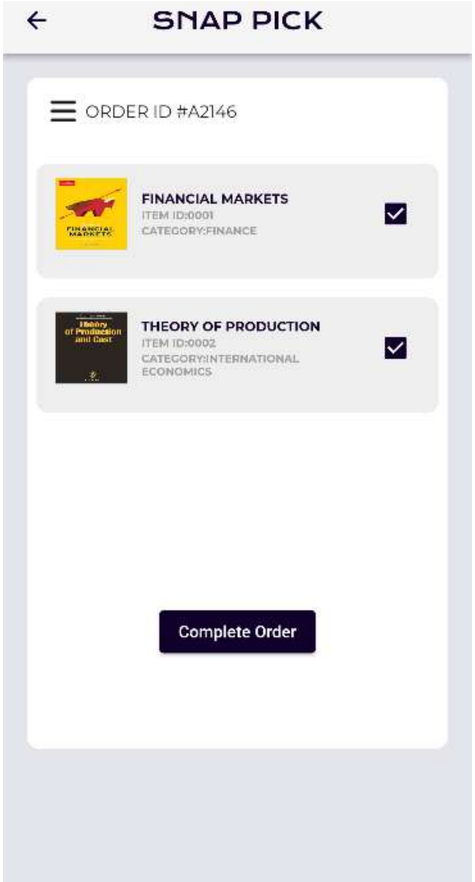

Figure 33: Packager Bin Details Screen

9. CONCLUSION

9.1. RESULTS

The app was handed to random people present on site for on-field testing and to demonstrate the app's performance. Moreover, overall user experience was noted and suggested changes from users for UI were incorporated.

Firstly, an order list was handed out with items present in different areas of site catalogued. Half the test users were asked to pick list items using the app, and the other half had to do it manually. Time for manual users was recorded using a stopwatch. For app users, a detailed summary with time and items on list was shown on the manager's end in the "Reports" page. Total user participation was 16.

On an average, a decrease in 6% was recorded in time. Over the course of one day, that would amount to 84 minutes saved.

In respect, a decrease in 180 Rs per day would be noted, assuming the daily wage for warehouse workers to be 125 Rs per hour. This means the manager can save almost 5400 Rs monthly by utilizing the app. Not to mention, the cost for daily paper-based checklists and hiring workers for managing these order-based lists is brought to zero as these are managed by the system automatically.

PICK LIST			
ORDER ID	QTY	ZONES	
A2145	3	A,A,B	
A2146	2	A,A	
A2147	2	A,B	
A2148	3	A,B,C	
A2149	2	C,D	
	APP TIME	MANUAL TIME	EFFICENCY
TEAM A	"00:10:33"	"00:11:13"	6%
TEAM B	"00:11:15"	"00:12:08"	7.00%
TEAM C	"00:08:28"	"00:08:55"	5%
TEAM D	"00:11:06"	"00:11:45"	6.00%
			6.00%

Figure 34: Proof of experiment

9.2. SDG

SDG 9, which aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation, can be addressed through the implementation of a Warehouse Management System (WMS).

The app helps to optimize warehouse operations, improving efficiency and productivity while reducing waste and inefficiencies. By automating many aspects of warehouse management, including inventory tracking, order fulfilment, and packaging, Snap Pick helps to streamline operations and reduce the need for manual labour, which can help to improve working conditions for warehouse workers.

In addition, it helps to reduce errors and increase accuracy, which can have a positive impact on product quality and customer satisfaction. This can help to improve the competitiveness of businesses and support the growth of the industrial sector in Pakistan.

Overall, the implementation of a WMS can contribute to the achievement of SDG 9 by promoting sustainable industrialization, supporting the development of resilient infrastructure, and fostering innovation in the logistics industry.

9.3. FUTURE PROSPECTS

- Solution can be easily extended to accommodate businesses that require picking/packaging processes or an automated managerial system.
- Performance check comprising of items picked by each picker over a course of time to be available to manager
- App automatically chooses employee of month based on performance
- If user is already in a zone and a new order comes in with items from that zone, the system automatically updates the pick list to incorporate these new order items
- Help manual to be shown when app is first launched or within the app for further guidance on how to use it. This will free up time from the manager's end to teach every new employee on how to fully utilize the system.
- Digital payment platform integration for automatic purchase of out-of-stock or in demand goods
- Co-aligning packaging with schedule of shipping companies associated with the warehouse

- Link system to actual e-commerce websites storing their products in that warehouse
- For larger warehouses, beacon tracking or Bluetooth tracking for improved precision
- Introduce other pick methods for manager to choose from, like batch & wave picking
- Employees can login via QRCode on their ID cards to further reduce pick time and for ease of use
- Scan item SKU to ensure correct item has been picked

9.4. CONCLUSION

The paper presents features and results after deploying "Snap Pick," an app which utilizes Augmented Reality (AR) to reduce pick time and package errors in warehouses. The app offers dynamic order handling through server-based operations and aims to decrease costs and errors by assisting managers in inventory tracking, personnel management, and selecting efficient picking schedules.

After deploying on field, an increase of 6% was noted in terms of speed as compared to manual picking. Furthermore, double checking of order items, one on picker’s end and the other on packager’s, ensured error rate was bought to a minimum.

In monetary terms, without employing any extensive technology, the entire warehouse process was digitized and daily cost for paper-based check lists was brought to zero.

The app's design can be extended to other pick and package scenarios.

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