



Empowering Informal Workers in Tanzania with an Automated Voucher Selling System: Co-design with Street Traders in Tanzania

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Abstract: *Street trading is a dominant form of informal work that sustains livelihoods in urban Tanzania. This study designed and developed an Automated Voucher Selling System (AVSS) to address challenges associated with the manual paper-based voucher system at Machinga Complex, Dodoma, including inefficiency, inaccuracy, fraud, insecurity, and environmental waste. The system design was guided by a Design Science Research (DSR) approach integrated with a co-design process. Qualitative data were collected through in-depth interviews with 31 street traders, followed by a focus group discussion with eight key informants, to identify user requirements. The AVSS was subsequently developed, demonstrated, and tested through iterative stakeholder engagement and training sessions. System evaluation was conducted via a survey of 79 street traders, assessing transaction speed, reliability, and usability. The results show that the AVSS effectively reduced operational challenges and contributed to environmental protection by eliminating paper-based vouchers. The study demonstrates that participatory, low-cost digital solutions can enhance efficiency and reliability in informal trade. It is recommended that similar initiatives be scaled to empower other groups of informal workers in Dodoma and across Tanzania, enabling broader application of digital technologies to support business growth and market expansion.*

Keywords: *Automated voucher selling system, co-design design process, design science research, street traders, Dodoma.*

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1. Introduction

The evolution of mobile communication from the first generation (1G) in the 1980s to the fifth generation (5G) represents a significant technological advancement that has transformed communication services (Singh & Singh, 2024). This progression has enabled a wide range of applications through the development of diverse technologies and standards (Park, Im, & Noh, 2015). The

introduction of fourth-generation Long Term Evolution (4G LTE), incorporating high-speed technologies such as Orthogonal Frequency Division Multiple Access (OFDMA) and Multiple-Input Multiple-Output (MIMO), has facilitated the expansion of wireless systems including WiMAX and Wi-Fi (Pahlavan & Krishnamurthy, 2021). These systems support various short-range applications, such as voice and video communication, short message services (SMS), and internet-based services (Hu, et al., 2015), which are increasingly accessed through

smartphones, feature phones, and personal digital assistants (Ali & Warraich, 2022). In sub-Saharan Africa, numerous information systems have been designed and deployed to resulting from the exponential technological advancement (Mramba, Rumanyika, Apiola, & Suhonen, 2017). The designed information systems serve both informal and formal workers by addressing sector-specific challenges. These systems have been applied in marketing, education, record keeping, agriculture, veterinary services, insurance, and weather information dissemination (Kapinga, Montero, & Mbise, 2018; Mwandosya, Montero, & Mbise, 2019; Mtebe & Kondoro, 2016; Ninsiima, 2015). Such technological interventions have contributed to improved service delivery and productivity, including street trading sector in Tanzania (Rumanyika, Apiola, Mramba, Oyelere, & Tedre, 2021). Street trading plays a vital role in providing affordable goods and services to urban populations; however, traders often face constraints related to financial exclusion, limited access to credit, inadequate record keeping, and exclusion from formal digital platforms (George, Msoka, & Makundi, 2023). To address these challenges, dedicated trading infrastructures, such as the Machinga Complex in Dodoma City, have been established to improve the working environment and support the economic activities of street traders (Laurent & Mushi, 2024).

Photo 1: Machinga complex building for street trading in Dodoma city
This premise, together with similar facilities established in various parts of Tanzania, was primarily constructed to

accommodate both stationary and mobile street traders (Mramba, 2022); however, it remains insufficient to accommodate all traders. Prior to the establishment of the Machinga Complex, the majority of street traders relied heavily on moving from one location to another in search of customers (Godrich, Juma, & Mfinanga, 2018). Despite the availability of physical trading spaces, mobile digital solutions continue to play a critical role in supporting traders' daily operations. In this context, mobile platform applications have emerged as the most practical digital tools, enabling street traders to interact with customers anytime and anywhere within Dodoma City (Rumanyika, Tedre, Apiola, & Mramba, 2019). This is largely due to the widespread use of mobile phones among street traders for communication with customers and other business stakeholders (Rumanyika, Tedre, Apiola, & Mramba, 2019).

Recognizing the potential of mobile communication and internet services in supporting informal businesses, a technology company known as "Airsurf" Technologies installed Wi-Fi access point to enable low-income individuals to recharge mobile phones and access affordable internet services. The company employs a paper-based voucher recharging system, which requires users to purchase printed vouchers and manually enter voucher codes prior to internet access (see Photo 1a-c). The vouchers are priced at TZS 1,000 for 24 hours, TZS 500 for 12 hours, and TZS 5,000 for one month.



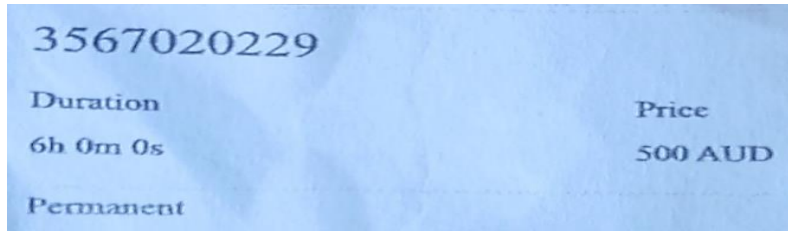


Photo 2 (a): The manual printed paper with voucher number

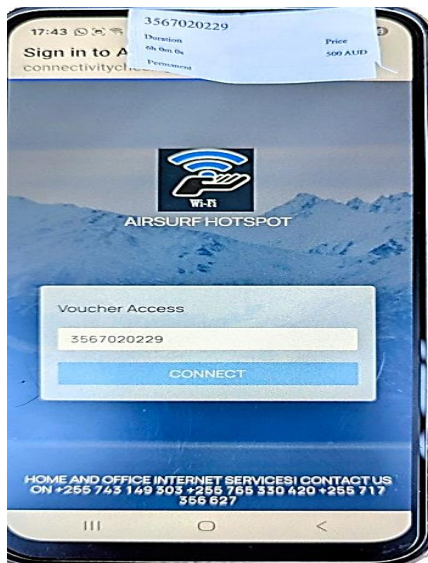


Photo 2 (b): The subscriber enters the manual voucher number to connect to the internet



Photo 2 (c): The subscriber is connected to the internet after the entering the voucher number

However, evidence shows that the paper-based voucher system faces numerous challenges, including handling difficulties, limited user understanding, inefficiency, inaccuracy, restricted accessibility, fraud, and insecurity. These challenges are further worsened by the street trading environment, which is exposed to natural factors such as wind and rainfall (Godrich, Juma, & Mfinanga, 2018). Consequently, conflicting views persist regarding the system's effectiveness, highlighting the need for academic intervention. This study addresses this gap by designing and developing an Automated Voucher Selling System (AVSS) tailored to street traders in Tanzanian context. The proposed system aims to streamline voucher distribution, enhance accuracy, reduce risks, and improve accessibility through a participatory design approach (Wacnick, Daly, & Verma, 2025; ILO, 2024).

To achieve the main objective of this study, a Design Science Research (DSR) approach was adopted, as it allows the application of multiple processes, including the

co-design method (Jakubeit et al., 2022). Similarly, this study employs a co-design approach to design and develop a voucher distribution system, namely AVSS. The primary contribution of this research is the design and development of an innovative automated voucher selling platform that empowers street traders to access internet services more easily and reliably while mitigating risks associated with paper-based vouchers, such as loss and physical damage. Evidence indicates that reliance on traditional paper vouchers exposes traders to operational inefficiencies, financial losses, and service disruptions, thereby limiting effective participation in digital service markets. By introducing a digital solution tailored to the needs of informal traders, this study enhances transaction efficiency, improves system reliability, and supports accurate record keeping. Furthermore, the study contributes to environmental protection by addressing the persistent problem of paper waste resulting from voucher printing and disposal. By replacing paper-based vouchers with a digital platform, the research promotes environmental

sustainability, digital inclusion, and economic empowerment among street traders at the Machinga Complex in Tanzania.

To achieve the main objective of this study, the following research questions are addressed:

- *RQ1: How can intercultural team co-design an automated voucher selling system contextualized for Tanzanian informal workers following the principles of DSR?*
- *RQ2: How can a team of potential stakeholders demonstrate, test, and evaluate an automated voucher selling system using principles of DSR approach?*

1. Literature Review

2.1 Automated Voucher Selling System

The use of paper-based vouchers in the communication and telecommunications industry has a long history (Hunt, 2016). These physical vouchers have been employed for various transactions, including food stamps and gift certificates (Parikh, Javid, Sasikumar, Ghosh, & Toyama, 2006). The body of literature reveals that most paper-based mobile recharging voucher schemes face numerous challenges that hinder their potential to enhance communication (Baah, 2019). These challenges include susceptibility to tampering and counterfeiting, risks of fraud and misuse, inefficiencies in the selling and distribution processes that can lead to delays, and the potential loss of access for legitimate users due to human errors, such as incorrect number entries by consumers (Densmore, 2012). Evidence indicates that the development of digital voucher systems began in the 21st century, fueled by advancements in telecommunications and information and communication technology (Hsu, Tu, & Huang, 2020).

Similarly, the recent advancements in mobile technologies and the Internet of Things (IoT) have resulted in the creation of more sophisticated online platforms and mobile applications (Sabeti, Shoghli, Baharani, & Tabkhi, 2021; Devagiria, Paheding, Niyaz, Yang, & Smith, 2022). Thus, implementation of AVSS aligns with Tanzania's national ICT policy (URT, 2003), which aims to create a reliable and effective environment for integrating ICT in the convergence of telecommunications, broadcasting, and information systems. This integration seeks to open new opportunities for citizens in both urban and remote areas, particularly for marginalized groups and informal workers. The primary goal is to empower these low-income individuals to leverage the potential of ICT for development (ICT4D), ensuring that everyone, including those previously excluded from development, can access opportunities and benefits (Heeks, 2020).

In addition, the United Nations (UN) endorsed ICT for Development (ICT4D) as a vital tool for socio-economic advancement and creating decent work in developing countries through various initiatives, including the 2030 Agenda for Sustainable Development, which includes 17 goals (UN, 2015). Unfortunately, street traders in Tanzania often lack access to decent jobs due to significant disparities in gender, education, business skills, and rural-urban geography. Therefore, deploying AVSS in the street trading context would effectively support the implementation of the UN Sustainable Development Goals (SDGs), particularly Goal 8.3, which promotes inclusive economic growth and decent work for all (UN, 2015).

2.2 Existing Information Systems Supporting the Informal Workers in Tanzania

Previous studies have shown that in Tanzania, many existing computer-based information systems have been designed and developed to solve problems in the agricultural sector (Mushi, Serugendo, & Burgi, 2022). The only few information systems which support the informal workers are such as: Mobile technology for enhancing the flow of agricultural information between small-scale farmers in Chamwino; Machinga mobile application; Mobile marketing application for entrepreneurship development; Crop protection information system for rural farmers, and Mobile technology for street traders (Misaki, 2021; Rumanyika, Apiola, Mramba, Oyelere, & Tedre, 2021; Kapinga, Montero, & Mbise, 2018). The evidence shows that informal workers already use several computer-based information systems such as mobile apps to support their activities such as access to market information (market prices of crops and contact crop buyers), veterinary care, weather updates, crop protection, customer's location, and insurance (Sanga, 2018). In addition, the study by Mramba et al. (2017) found that there are bulky of mobile apps in Tanzania that provide general services to both formal and informal workers. The other main types of mobile application used by informal workers are social media platforms like Instagram, WhatsApp, Facebook, and Twitter (Weismueller, Harrigan, Wang, & Soutar, 2020). Majority of mobile applications offer simplified platforms to facilitate informal workers' routine activities, although, the popular do involve some costs (Mramba & Rumanyika, 2020).

2.3 Integrating Co-design Process in DSR

The integration of co-design processes in information and communication technology for development (ICT4D) field

has been used in the design and development of numerous computer-based information systems in the emerging economies (David, Sabiescu, & Cantoni, 2013). In ICT4D viewpoint, co-design involves the creation of information systems through a shared vision, social learning, and mutual understanding between the designers and the participants (Ssozi-Mugarura, Blake, & Rivett, 2016). The advantage of co-design is that it considers the perspectives of everyone to be involved in the design process, even though those desires and wishes may be contradictory. In ICT4D projects, co-design is used by practitioners, researchers and international development organizations to strive towards sustainable community development (Kang, 2010). Thus, co-design is closely associated with participatory design (PD) or is an updated PD (David, Sabiescu, & Cantoni, 2013). The two approaches of co-design and PD have been influential to each other in their historical progress. Both co-design and co-creation share the keys principle of involving stakeholders in the design process to ensure that the end product meets user needs, and has a high rate of being adopted (David, Sabiescu, & Cantoni, 2013). The users' needs are obtained from the non-designers such as external stakeholders, or influential people who belong from various disciplines such as marketing, engineering, sales, customers, or people with special needs, with different backgrounds, experiences, interests, and roles to play within a project (Pihlainen, Montero, & Kärnä, 2017). The usefulness of infusing co-design process in this study is that it promotes a strong

relationship of human-computer interaction (HCI) among the experts and local communities (Dearden & Haider Rizvi, 2015) in accomplishing actions and activities that transform human development that is highly emphasized in ICT4D projects.

2. Methodology

3.1 Research Design

This study was guided by the design science research (DSR) approach (Gregor & Hevner, 2013). In recent time, DSR has been used to design and develop information system interventions to address contextual problems facing users in developing countries (Agbo, 2022). DSR aims at designing solutions to real-life challenges rather than conducting laboratory-based research by making use of available opportunities, resources, and contextual strengths (Hevner & Chatterjee, 2010). DSR informed studies typically use a mixture of research, framework and design approaches, including participatory co-design, co-creation, and software prototyping (Agbo, 2022). This study employed one of the DSR frameworks as proposed out by Johannesson and Perjons (Johannesson & Perjons, 2014). The framework has five chronological phases: problem explication, requirement definition, design and development, demonstration, and evaluation (see Figure 1).

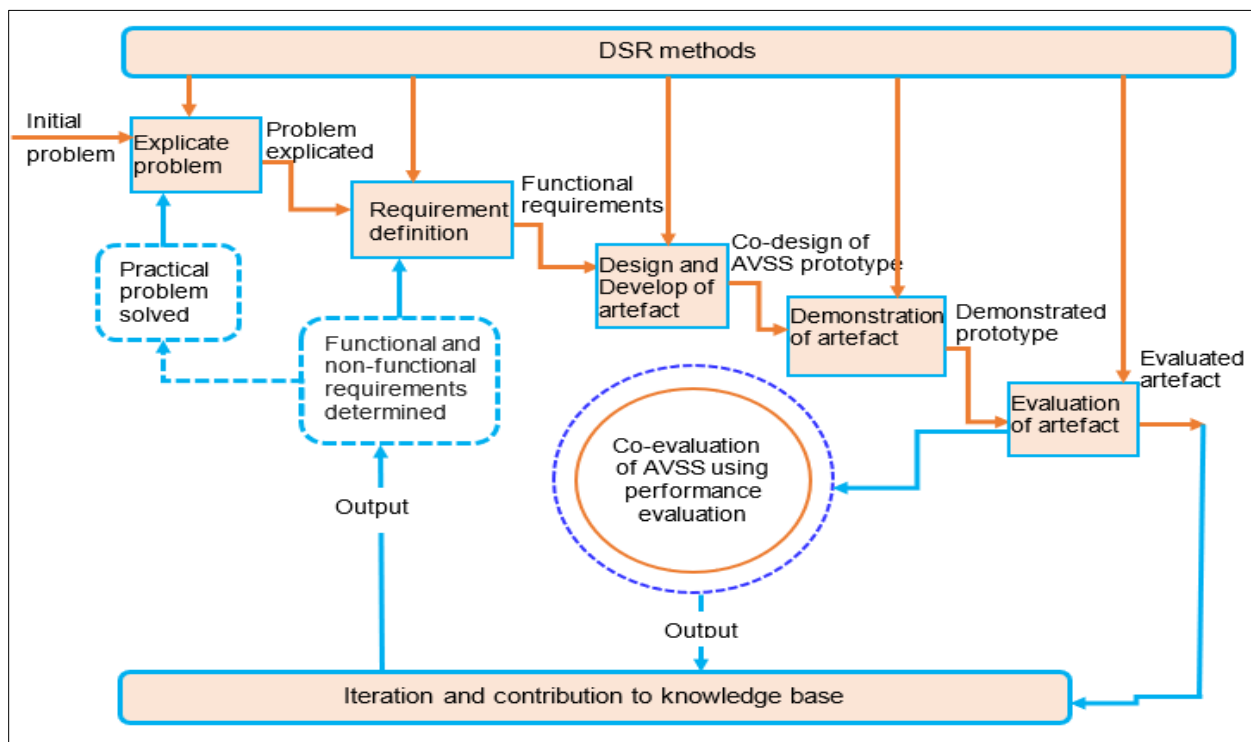


Figure 2: DSR framework (adapted from Johannesson & Perjons, 2014, p. 77, to suit the study).

The DSR framework by Johannesson and Perjons (2014) allows the adoption of other design methods including co-design to strengthen the main DSR framework. Similarly, the framework offers a structure that can incorporate a mixture of research methods, e.g., the requirements for the design and development AVSS could be gathered by using a mixture of qualitative and quantitative methods (Johannesson & Perjons, 2014). Moreover, the framework offers clear iterative procedures for measuring the inputs and outputs of each activity in each phase. If properly adopted, the framework makes it possible to project the requirements that fulfil the needs of the stakeholders and are thoroughly constructed, implemented, and evaluated (Baskerville, Baiyere, Gregor, Hevner, & Rossi, 2018). In this study, several activities were carried out at each stage of the selected DSR framework based on the nature of street trading environment (Haule & Chille, 2018).

3.2 Participants, Data Collection and Analysis

Data was collected through face-to-face interviews and focus group discussions (FGDs) with selected number of informal workers majority being street vendors. The majority of the selected street vendors were those who are stationary and mostly conducting their business activities at “Machinga complex” in Dodoma city. Eventually, the researcher interviewed some selected number of street traders to get understanding how they are largely informed regarding paper-based vouchers, how do they perceive, feel, experienced, and the type of practical problem that was identified. In the first phase of the study (see Photo 1), the researchers conducted interviews with 14 street traders, followed by a preliminary analysis of the collected data. Despite this initial analysis, several new themes continued

to emerge, indicating the need for further data collection. Consequently, a second phase was undertaken, during which an additional 14 interviews were conducted. However, new themes still appeared, prompting the researchers to proceed to a third phase. In this final phase, only three interviews were conducted, and no additional themes were identified. At this point, the researchers concluded that data saturation (Naem, Ozuem, Howell, & Ranfagni, 2024) had been reached. Therefore, further data collection was unnecessary because could not provide new information. A total of 31 street traders were interviewed to comprehensively explore the research phenomenon and to identify their specific requirements for the proposed digital platform. Following the interviews, a focus group discussion (FGD) was conducted with eight key informants, including the chairperson of Machinga Complex and members of the entire premises management team, to gain additional insights and validate the findings from the individual.

The data, from the recorded transcripts and audio recordings, were analyzed using thematic analysis, following the six-phase framework outlined by Braun and Clarke (2006) to guide the systematic process within the dataset Braun and Clarke (2006). These phases include: (i) familiarization with the data by taking notes; (ii) generation of initial codes, by coding the most compelling parts of the data; (iii) grouping of codes into potential themes; (iv) reviewing of themes, checking them against the data to ensure that no potential themes had been missed; (v) finalization of the naming of the themes; and (vi) production of a research report out of the themes (Ahmed, et al., 2025). In this study, the combination of the results from interviews and FGDs resulted into the following functional requirements in (Table 1) which determine the overall of what was required in a proposed digital platform.

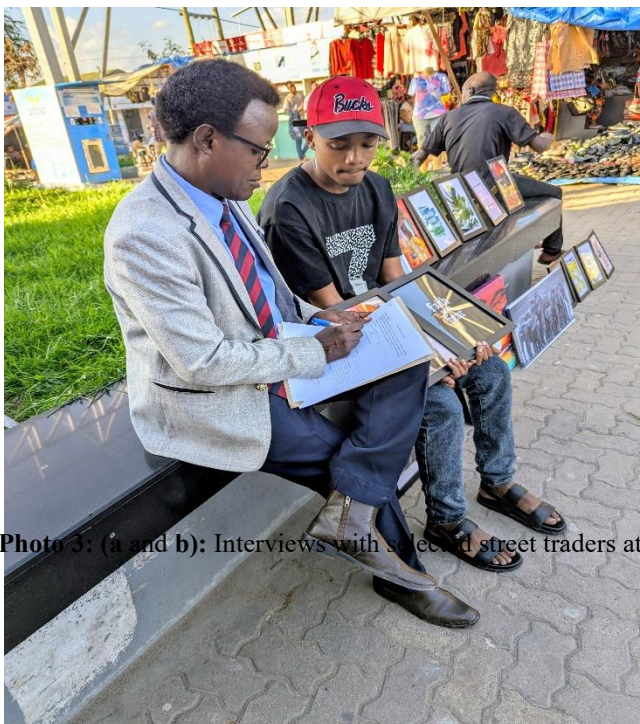


Photo 3: (a and b): Interviews with selected street traders at Machinga complex

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b

3.3 Functional Requirements Determined by Street Traders

For the sake of building the initial prototype, a list of user requirements was suggested as tabled in (Table 1).

Table 1: A list of requirements suggested by stakeholders

Type of requirement	Explanations
User registration and authentication	For secure processes for user registration and login
Voucher purchase	To enable the end-users to purchase vouchers through multiple channels (e.g., mobile app, Unstructured Supplementary Service USSD)
Voucher redemption	Applied as the secure methods for voucher redemption
Transaction history	To enable the end-users mainly the vendors to access transaction history and reports
Integration with mobile money	For seamless integration with popular mobile money platforms
Real-time notifications	To enable the end-users to receive instant notifications for successful transactions.
Voucher details	Storing information about vouchers, including codes, values, and expiry dates.
Usability functionalities	User friendly, ease to learn, intuitive navigate, interesting and accommodates the all aspects of perceived ease -of-use (PEOU)

3.4 Technologies Used in the Design of the AVSS

Numerous technologies were applied in designing, developing, and ensuring the security of AVSSS. These technologies are as highlighted and explained in table 2.

Table 2: Numerous technologies applied in the design and development of AVSS

Technology	Descriptions
Ubuntu	It was used because of being a free operating system and free open source for desktops and laptops
Python	Python is a very high-level, dynamic, object-oriented, general purpose programming language that uses interpreter and can be used in a vast domain of applications
Gammu	It is a technology used for controlling the GSM-based mobile phone which is a form of networking
MySQL	It was used for back-end data storage and management
PHP	It was used as the web-based programming language for the dynamic web system contents
HTML	It was used for developing websites' pages. Used for formatting and displaying data
JavaScript	It was also used as the programming language that executes within a browser and the language for Android systems which are expected to be supported by mobile devices
CSS	It was used for front-end of the system design to describe how HTML element can be displayed

3.5 Ethical Considerations

The ethical approval for this study was obtained from the Dodoma Regional Administrative Secretary (RAS). All research procedures were conducted in accordance with established ethical guidelines, including obtaining written informed consent from participants, ensuring confidentiality of responses, and informing participants of their right to withdraw from the study at any time

3.6 AVSS Architectural Design

The system architecture design presented below is an integrated Wi-Fi access control framework that combines voucher-based authentication with mobile money payment mechanisms. The design is structured into three logical zones which include: (i) admin zone, (ii) payment processing zone, and (iii) customer zone. Each zone is responsible for a distinct set of functions as described in the next paragraphs.

First, the admin zone (AZ) is responsible for the generation, management, and storage of Wi-Fi voucher credentials. Within this zone, the Omada Controller generates voucher codes that define access parameters such as session duration, bandwidth allocation, and validity periods. These vouchers are uploaded and managed through an admin application or admin panel. The admin panel acts as the interface for configuring voucher batches and synchronizing them with backend services. All voucher information, along with transaction records and SMS logs, is stored in a centralized database. This database supports traceability, accountability, and system auditing, which are critical for both operational oversight and regulatory fulfillment.

Second, the payment processing zone (PPZ) facilitates the validation of user payments and the controlled release of voucher codes. Mobile money payments made by users are confirmed through SMS notifications received on a dedicated payment phone. These payment confirmations are processed by a voucher application, which verifies the

authenticity and correctness of the transaction before associating it with an available voucher from the database. Thus, upon successful validation, the system retrieves an unused voucher code and records the transaction details. The voucher code is then transmitted to the user via SMS, ensuring reliable delivery even in cases where automated portal interactions may fail.

Third, the customer zone (CZ), which focuses on the user experience and access authentication process. After receiving the voucher code, the customer connects to the Wi-Fi network using a personal device and is redirected to a captive portal. The captive portal facilitates the entry or automatic pasting of the voucher code, thereby reducing user errors and improving usability. The entered voucher is subsequently verified by the Omada Voucher Authentication mechanism, which communicates with the controller to confirm the voucher's validity. Once authenticated, the system grants internet access according to the predefined voucher constraints.

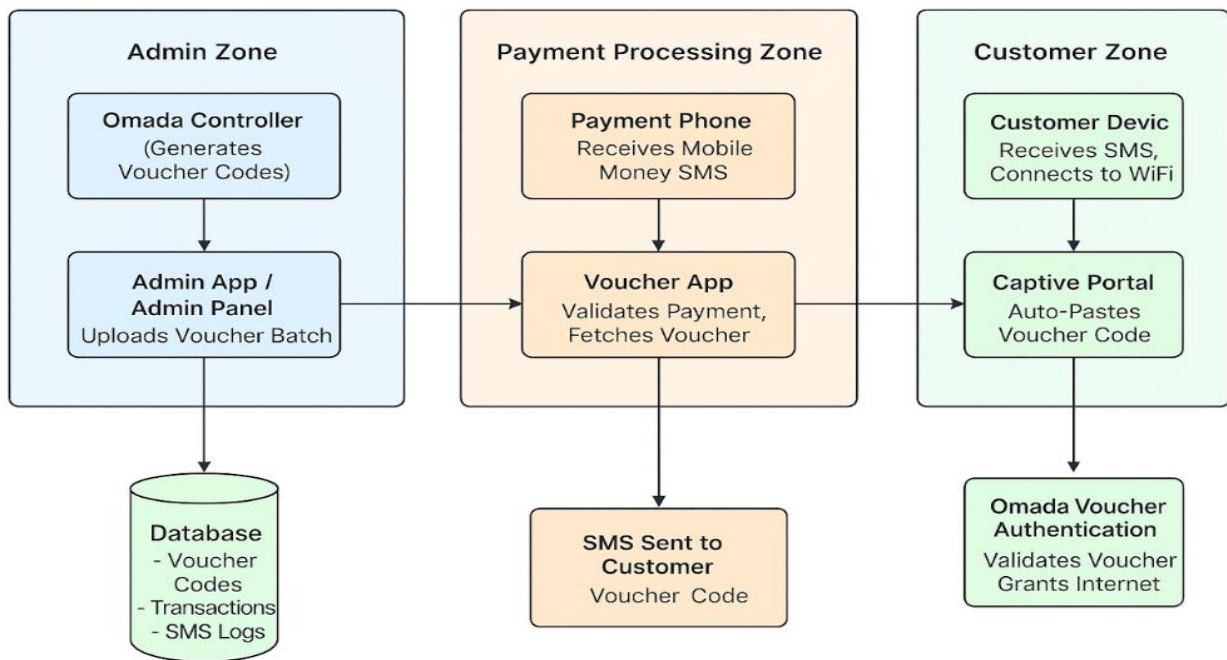


Figure 2: AVSS architectural design

3.7. How AVSS Works with Mobile Service Providers

Taking an example of two main mobile network operators (MNOs) of Vodacom and Airtel, operating in Tanzania (Ndunguru, 2025). Usually, street traders send the short messaging services (SMS) or they dial e.g., (*150*00# for

Vodacom or *149*99# for Airtel mobile network operator (MNOs) companies. Thereafter, they send USSD code to Vodacom or Airtel mobile switching centres (MSCs). After receiving the message, Vodacom, or Airtel (MSC) sends the transaction to the AVSS server. Then, the AVSS server verifies the transaction and sends the voucher number to the customer. Finally, the customer enters the voucher number into AVSS portal (Wi-Fi portal). Finally, the

customer is now able to access the internet at minimum cost (Photo 3).

3.8 Use Case Modelling for AVSS

Use cases diagrams (UCD) explain how one or more actors interact with the AVSS. This use case tells what the system does regarding its functional requirements with respect to user's inputs (Sommerville, 2016). The activity of drawing the use cases in this study started by initially identifying main actors of the AVSS. According to (Sommerville, 2016) an actor represents a role played by every individual who interacts with the system. We identified our actors into three categories which include: (i) the voucher redeemer

(street vendors), (ii) the voucher seller (AVSS system administrators, and iii) any customer's choice of a mobile network operator (MNO) (See Figure 2). The choice to adopt use case diagram (UCD) technique is based on the grounds that it is easy to interpret and understood during software development and easy to be understood by local users (street traders). The experience show that majority street traders possess different backgrounds, contextual knowledge, and experience. UCD summarizes all important information related to the AVSS, which is being demonstrated in one drawing (Misbhauddin & Alshayeb, 2015). A customer, as the normal user, has to create an account through AVSS to get the service from the voucher vending point, the voucher vendor performs the management of the customer's information.

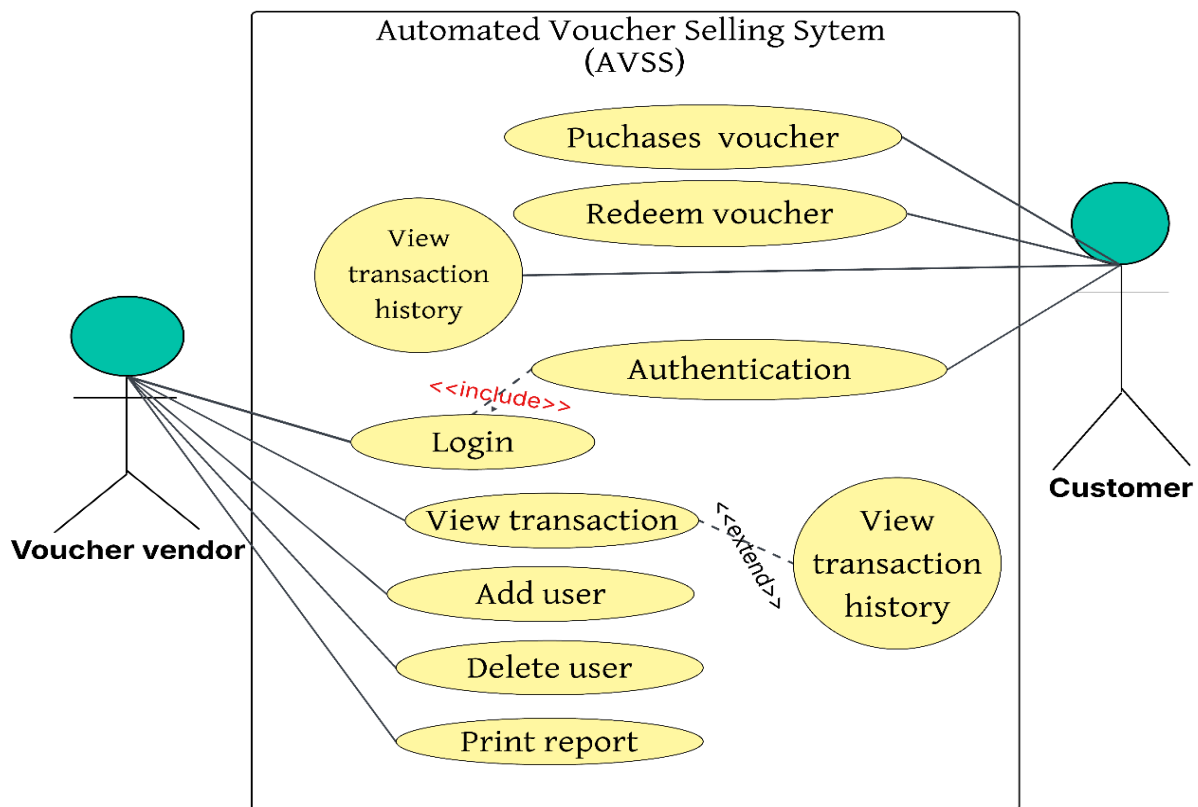


Figure 3: AVSS use case diagram representing the role played by each actor

3.9 AVSS Source Codes

In this sub-section, the part of the sources codes are presented to justify the design technologies used to build the system. A part of justification one can executes, merely load, reset and run.

```
<?php
session start();
// Check if user is logged in
if (!isset($_SESSION['user']) || ($_SESSION['user'] !=
"admin" && $_SESSION['user'] != "user")) {
// Redirect to login page or handle unauthorized access
header("Location: index.html");
exit();
```

```

}
// Your existing HTML and PHP code for admin dashboard
// Make sure everything inside <body> is within PHP tags
?>
<?php
// Database credentials
$servername = "localhost";
$username = "root";
$password = "rootpass";
$dbname = "kalkun";
// Handle user registration
if ($_SERVER["REQUEST_METHOD"] == "POST" &&
isset($_GET['action']) && $_GET['action'] == 'register')
{
// Create connection
$conn = new mysqli($servername, $username, $password,
$dbname);
// Check connection
if ($conn->connect_error) {
die("Connection failed: " . $conn->connect_error);
}
// Sanitize inputs
$first_name = $conn->real_escape_string($_POST['first_name']);
$last_name = $conn->real_escape_string($_POST['last_name']);
$username = $conn->real_escape_string($_POST['username']);
$password = $conn->real_escape_string($_POST['password']);
$phone_number = $conn->real_escape_string($_POST['phone_number']);
// Prepare and execute SQL statement
$sql = "INSERT INTO voucher_user (first_name,
last_name, username, password, phone_number)
VALUES ('$first_name', '$last_name', '$username',
'$password', '$phone_number')";
if ($conn->query($sql) === TRUE) {
// Redirect to prevent resubmission on page refresh
header("Location:
submit_user.php?action=view_users&register_status=su
ccess");
exit();
} else {
$result = $conn->query($sql);
if ($result->num_rows > 0) {

```

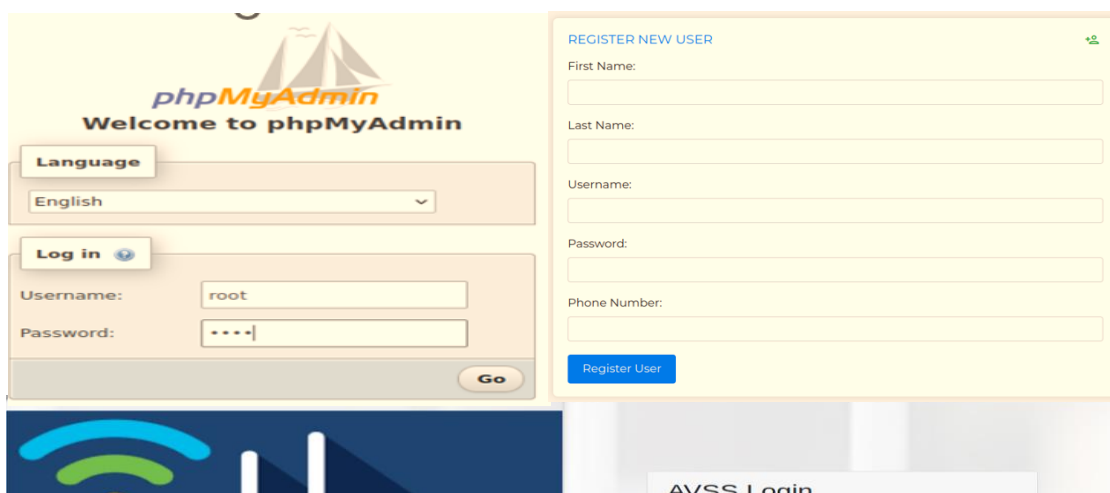
```

echo '<table class="table">';
echo '<thead>';
echo '<tr>';
echo '<th>ID</th>';
echo '<th>First Name</th>';
echo '<th>Last Name</th>';
echo '<th>Username</th>';
echo '<th>Phone Number</th>';
echo '<th>Action</th>';
echo '</tr>';
echo '</thead>';
echo '<tbody>';
while ($row = $result->fetch_assoc()) {
echo '<tr>';
echo '<td>' . $row['id'] . '</td>';
echo '<td>' . $row['first_name'] . '</td>';
echo '<td>' . $row['last_name'] . '</td>';
echo '<td>' . $row['username'] . '</td>';
echo '<td>' . $row['phone_number'] . '</td>';
echo '<td>';
echo '<a
href="submit_user.php?action=delete&user_id='
$row['id'] . '" onclick="return confirm('\Are you sure you
want to delete this user?\')">';
echo '<span class="material-icons-outlined text-
danger">delete</span>';
echo '</a>';
echo '</td>';
echo '</tr>';

```

3. Results and Discussion

The system designed by the team of software developers resulted in a number of graphical user interfaces (GUI). The interfaces define how the AVSS will facilitate informal workers to purchase the voucher through their mobile application in a situation that is more flexible, secure, efficient, and user friendly. Some of the generated AVSS interfaces are presented, and their workability is described in the following sub-section. The first group of the generated user interfaces (UI) represented by a snapshot (Photos 4a, b, c, and d). These snapshots show the steps inquired by a trader to register in the system so as to obtain the user's name and password which provide the user access to the system.



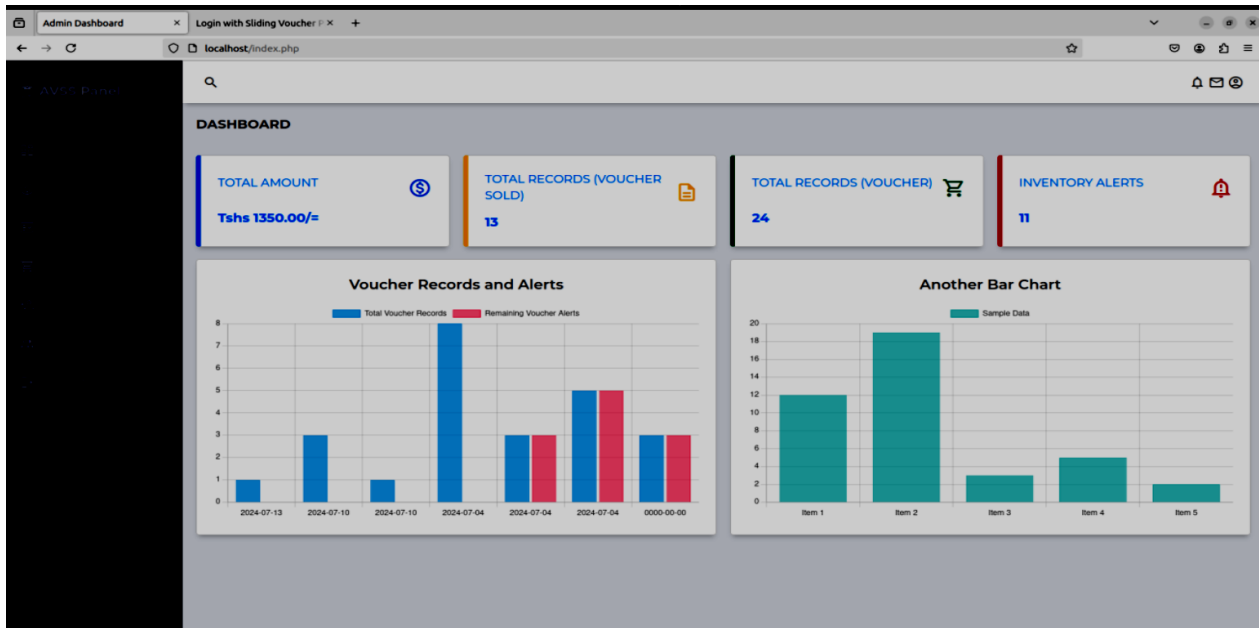


Photo 4 (a, b, c and d): The user interfaces for login and registration of customers in AVSS
The second group of the generated interfaces are represented by (Photo 4) and display the generated

feedback report which justifies that the user has purchased the voucher successfully.

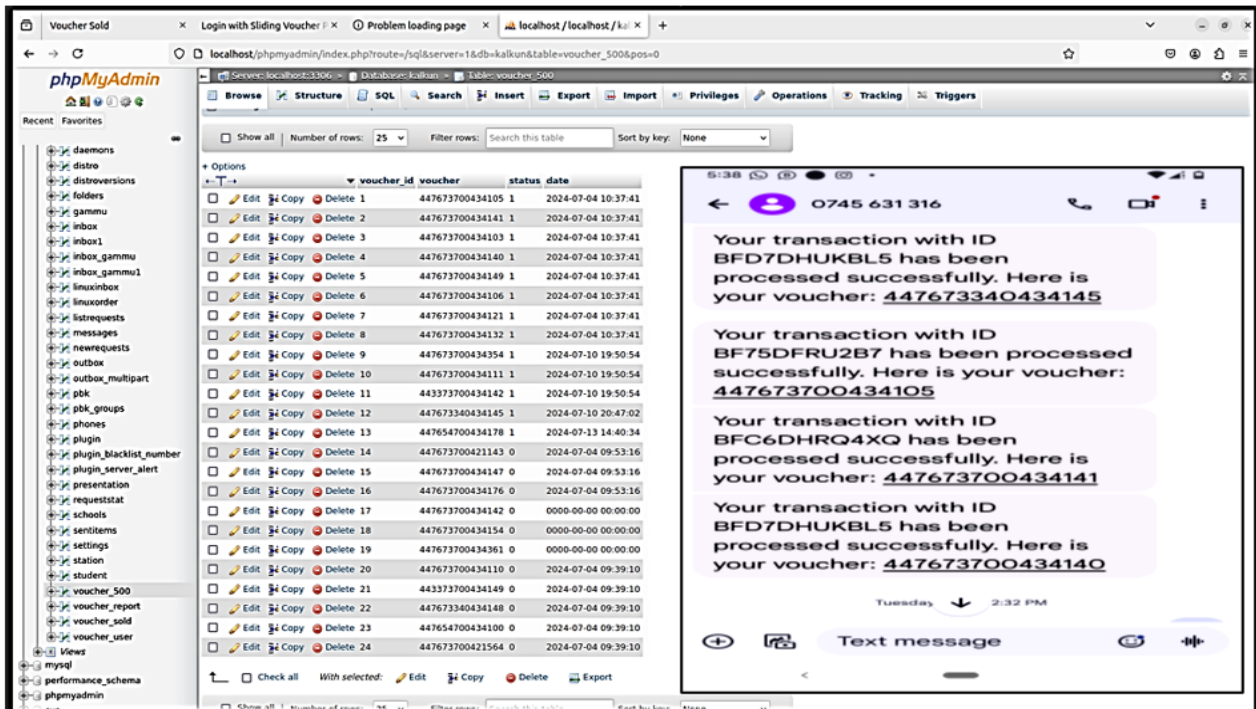


Photo 4: The AVSS generated report

4.1 AVSS Demonstration and Testing Process

In DSR-oriented projects demonstration and testing activities can be parallel conducted to examine whether the designed artefact is feasible and can work to solve real problems designed for (Johannesson & Perjons, 2014). Demonstration includes communicating with end-users about how the designed artefact operates through verbal illustrations and examples of real-life cases. Testing involves practice carried out to observe the workability of the prototype and compare it with existing systems. In this study, the researchers trained and demonstrated AVSS product prototype to the 40 selected groups of street traders with the consideration of gender balance. The training focused on showing how the AVSS operates step-by-step. The researchers considered a range of imaginary situations and environments for testing to obtain results that would emulate real-street trading environments. Thereafter, the participants were obliged to submit their smartphones to the group of researchers to install the executable APK file. The first ten successful traders were allowed to share the APK file with others through WhatsApp and they had to wait for further directives. Then, street traders were instructed to open and register in the system using their personal login credentials. Thereafter, street traders were instructed to start doing the practice by purchasing vouchers for internet subscription. The feedback was immediately sent to them (see Photo 4a and b) interface.

At this stage, the researchers employed two types of system testing which include: integration testing (IT) and user acceptance testing (UAT). Integration testing was conducted to verify whether different components work together seamlessly (Shahabuddin & Prasanth, 2017). This testing phase ensures that the interfaces between components are functioning correctly and that data flows as expected across the system. The resulting integration test results are shown in (Photo 5) of the snapshot.

Photo 4: The software integration results

Regarding UAT testing, we involved all the end-users to test the system to ensure it meets their needs and requirements. The major aim of conducting UAT was to create a sense of feeling confidence among the end-users of the AVSS (Pandit & Tahiliani, 2015). In the UAT testing, we considered the requirements-based process in which the user's stories and acceptance criteria form the basis of the UAT process. UAT phase is crucial for

validating whether the system is user-friendly for the specified user requirements.

4.2 Evaluation of AVSS

In the projects that are guided by DSR approach, the evaluation of the system or prototype is done to determine the suitability of the artefact and to assess whether it is helpful in solving the practical problem that motivated its design. Evaluation in DSR helps the end-users realize the strengths and weaknesses of the developed system (Touray, Salminen, & Mursu, 2013). Thus, evaluation determines how well the artefact can solve the explicated problem and informs the extent it fulfils the users' requirements (Venable, Pries-Heje, & Baskerville, 2012). In this project we evaluated the AVSS by analyzing several key metrics including transaction speed, system reliability, and usability. To accomplish the evaluation process, a survey method was used to gather information from 79 street traders. Our questionnaires used five-point Likert scales ranging from (1 = *not at all true*, 2 = *not true*, 3 = *somewhat true*, 4 = *very true*, and 5 = *completely true*) and written in Kiswahili. The statistical package for social science (SPSS) was employed to analyze the respondents' questions, and the results are provided showing the meaning, standard deviation, and the mode in the next sub-subsections.

4. 2.1 Evaluation Based on System Transaction Speed

The evaluation results presented in Table 3 indicate that the AVSS effectively supports real-time processing, allowing end-users to purchase and redeem vouchers instantly, with a mean score of 4.75 (indicating "*very true*") and (SD= 0.56). This implies that AVSS was purposefully designed to smoothen voucher transactions, and thus, replacing the traditional paper-based system deployed in the past. The close clustering of the standard deviation around the mean further reinforces that the design goals were successfully met and the system operates effectively. Similarly, the results show that the AVSS backend performance optimizations ensured minimal latency and quick response time during peak usage periods with the average mean of 4.54 (indicating "*very true*") and the (SD=0.66). These results are similar with the results by (Mahmood, Zen, & Othman, 2014) which show that in typical 4G heterogeneous networking environment technology-assisted networks, the service providers wish to offer to users greater bandwidth, reliability, security, and minimal delays. The major objective is thus to ensure appropriate service provision to applications such as voice, mobile commerce, videoconferencing, location-based services and other customized personal services.

Table 3. Evaluation based on system transaction metrics

Item	Evaluation metrics	Mean	Mode	SD
#1	AVSS can handle real-time processing by allowing the end-users to purchase and redeem vouchers instantly	4.75	5.00	.56
#2	AVSS backend performance optimizations ensured minimal latency and quick response times during peak usage periods	4.54	5.00	.66

4.2.2 Evaluation Based on System Reliability

In Wireless Networks Local Area (WLANs) reliability is measured in terms of how the network data for users is high-speed over large areas is terms of kbps for pedestrians in slowly moving in small areas and kbps for the indoor offices and stationary users. Our evaluation results from the end-users show that the designed AVSS was available and reliable with the mean score of 4.56 (indicating “*very true*”) and the (SD= 0.65). This indicates that the end-users of the mobile application experienced minimal downtime and robust error in handling intended services such as voucher purchase and receiving the feedback from the MNOs. In the case of regular backups to ensure disaster recovery plans for data integrity, the mean results score was 4.48 (indicating “*very true*”) and (SD=0.74). These results correspond with the results by (Sachan, Lakhani, & Poddar, 2025), which reveals that majority of WLANs-support systems should be ensured with maximum security of data to ensure that the information transmitted remain unchanged so as to protect the end-user’s information and

to intensify their trust to the designed system. In this project, the integrity of end-users’ information was ensured by adopting Ubuntu as for operating system because in reading the SMS entered the modem were easy to process due to the availability of Gammu daemon service (read and write). Similarly, Gammu software can process concurrent transactions and provide real-time reply. In server side of the system the researchers used Python programming language was used for back-end operations because it is powerful and current programming language that has used for back-end operations. Therefore, Python was used to capture an incoming outgoing SMS for the purpose of obtaining sender number for out reply through crone jobs. Similarly, the results show that AVSS streamlining process is automated in nature with the mean score 4.66 (indicating “*very true*”) and (SD=0.57). The results indicate that the AVSS has potential mechanism of reducing manual intervention, saving time, and reducing human errors. AVSS design architecture has detection methods that analyze mobile network traffic from many users and offer complementary means for encrypting the messages of end-users.

Table 4: Evaluation based on system reliability

Item	Evaluation metrics	Mean	Mode	SD
#1	AVSS has high availability and reliable, with minimal downtime and robust error handling mechanisms	4.56.	5.00	.65
#2	AVSS has regular backups and disaster recovery plans to ensure data integrity and system availability in case of failures.	4.48	5.00	.74
#3	AVSS streamlined process is automated in nature and reduces manual intervention, saving time and reducing the potential for human errors	4.66	5.00	.57

4.2.4 Evaluation Based on System Usability

Usability evaluation was conducted to assess the ease with which end-users’ majority being the street traders and other

visiting customers were able to: navigate, learn, understand, interested use the system and how attractive it was in terms of satisfying users. In this research, usability evaluation was a continuous process, with feedback recorded along with (Table 5).

Table5: Evaluation based on system usability

Item	Evaluation metrics	Mean	Mode	SD
#1	Users found the interface easy to navigate, reducing the learning curve	4.56.	5.00	.65
#2	The AVSS system is user-friendly or ease to use	4.42	5.00	.67
#3	The AVSS system is easy to learn	4.68	5.00	.60
#4	The AVSS system is an interesting system to use	4.51	5.00	.73
#5	An effective user's feedback mechanism of AVSS leads to user satisfaction	4.66	5.00	.57

In the evaluation process for usability aspects, each evaluated metric has a significant meaning in terms of one previously defined user requirements. The first and foremost is easy to navigate or intuitive navigation with mean score 4.56 (indicating “*very true*”) and (SD=0.65) assessed how the end-users could navigate several pages without exerting much mental effort. The second, ease of use is concerned with evaluating how the end-users of the prototype found it easy to register and enter without undergoing numerous procedures with mean score 4.42 (indicating “*very true*”) and (SD=0.67). The third, ease to learn metric with mean score 4.68 (indicating “*very true*”) and (SD=0.6) assessed how easily the users could intuitively learn and complete basic tasks with a system for the first time without applying the training manual. The fourth, very interesting with mean score 4.51 (indicating “*very true*”) and (SD= 0.73) implies how the end-users were interested on innovative design which carter for the problem of paper-based voucher purchase. The last, satisfaction assessed with mean score 4.66 (indicating “*very true*”) and (SD =0.57) assessed if the end- users were satisfied with the system by utilizing it to conduct transactions receive feedback, reduce some costs, ensure security, and improve business performance at the workplace. The overall mean average that was computed for all usability aspects scored a mean of 4.5 (indicating “*very true*”) which implies that many potential respondents who used the system during the testing period concur that it was well suited for support street traders’ activities.

3.3 Discussions

The discussions of the results for this project are structured and discussed based on research questions RQ1 and RQ2.

- *RQ1: How can intercultural team co-design an automated voucher selling system contextualized for Tanzanian informal workers following the principles of DSR?*

The general results show that the team of software developers from the College of Business Education (CBE)

teamed up with the selected number of stationed street traders to identify the potential requirements and deployed the co-design principles of ethics, safety, trustworthiness, equity, transparency and accessibility to design the AVSS. To every stage of the chosen DSR framework the co-design principles were infused. Ethics were protected by developing the sense of cultural humility, and value preservation to avoid biasness among the participants. This was introduced to enable co-design practice that would develop a common language for design, facilitating stakeholders’ engagement, allowing people from different backgrounds to think about design and communicate ideas with a shared understanding.

Safety was considered in the aspect that the team of software developers and street traders were emphasized on the value of feeling connected with common vision and no one could hurt another due to having the vested interest in the outcome of a project and have a lot of expectation from the project. Trustworthiness principle was ensured mainly during system’s requirement definition stage whereas through focus group discussion, brainstorming, diagrammatic sketches, and scenarios numerous information and functionalities that would guide the development AVSS system were gathered. This is a key foundation of co-design process, which avoids dividing people e.g., users, software developers, clients, researchers, thus, instead, co-design emphasizes creating technologies together, with respect to different individuals’ backgrounds. The infusion of the co-design process among the team of software developers and other participants helped to create trust between the researchers and street traders with the approach, which is well-thought-out to bridge the gap, building rapport, as well as providing enthusiasm which can critically overcome the design challenge expected to arise.

Equity and transparency principles were accommodated through several local champions’ workshops, meetings, and group discussions among the stakeholders, the

approach which is well-thought-out to bridge the gap, building rapport, as well as providing enthusiasm which can critically overcome the design challenge expected to arise. This logic of the intervention anticipates that there is experience of equality and transparency by having equal chance and freedom of expression among participants. Thus, their ability to address the feelings, wants, and expectations evolve into supportive solidarity, transparency, and more empowered environment the stakeholders are knowledgeable with system's design outputs and even being in position to challenge the structural conditions.

Accessibility element of co-design process inclusion in our design was infused by translating the designed output into different languages to enable various end-users to access, share the product, and content with a wider audience, thus, expanding accessibility. The essence of expanding accessibility through the translated language is to empower the local people to manage their business activities through affordable mobile technology. Mobile technologies are the primary point of access to the internet in many areas in the country, especially those with mobile broadband connections or fiber backbone. The evidence show that 53.5% which is equal to 33 million people of had access to the internet (Kalula, Dida, & Zaipuna, 2024) and up to quarterly of year 2024 around 81% of the mobile connections in the country were broadband ranging from 3G to 5G (Komba & Komba, 2024).

- *RQ2: How can a team of potential stakeholders have demonstrated, tested, and evaluated an automated voucher selling system using principles of DSR approach?*

The answers to this research question are provided in the following paragraphs as follows:

After the design and development of AVSS through DSR framework guidelines, the software was demonstrated to the potential stakeholders. The software demonstration was supported by multiple workshops and meetings which involved communicating verbally and observing with end-users about how the designed system operates. After demonstration process, the system was tested involving the potential multi-stakeholders who did the testing in indoor training through instructions and practices. The feedback was received from the voucher seller which emulated the success of indoor testing. However, to ensure reliability, real-world testing was conducted to validate the functionality of the prototype. Technically, this type of testing is known as structured walkthrough field testing (Alsayed & Bilgram, 2017). Thereafter, the software was evaluated based on the number of performance metrics, and usability criteria.

4. Conclusion and Recommendations

5.1 Conclusion

This project report discusses the development process, features, and benefits of the AVSS, by highlighting its potential impact on improving voucher distribution for informal workers mainly street traders and some customers in one part of Tanzania. There are numerous contributions which include: First, successfully design of AVSS system that is designed in local context. The output has features which were technologically mediated, streamlining empowering stationed, mobile street traders and other potential stakeholders in vending domain to access internet connection at the cheap price and to carry out key tasks business value exchange. In the ICT4D field, the design of the AVSS software was made possible by the knowledge provided by the community after visualizing the problem and identifying the opportunity of the installed nearby Wi-Fi technologies. Thanks to its contextual and goal-oriented effort to solve the problem paper-based purchasing and reducing the high cost for internet subscription among street traders and other stakeholders in Dodoma city.

5.1 Recommendations

This study was conducted in Dodoma, a region located in central Tanzania. The major objective was to design and develop the AVSS which focused on addressing the challenge of inefficiency inaccuracy, limited accessibility, and fraud associated with paper-based voucher purchasing methods. The study's outcome is the AVSS, which was co-designed by the researchers in collaboration with street traders stationed at the "Machinga" complex. The output of this project is a locally contextualized AVSS prototype designed to streamline voucher purchases for internet-based subscriptions at low-cost, and thus, reducing the reliance on manual voucher purchasing methods that exist currently. The study was guided by the DSR method and largely adopted the DSR framework laid out (Johannesson & Perjons, 2014) which has five chronological phases that can be carried out incrementally, linearly, or iteratively. The researcher identified that for the beginning the study outcomes gave a promising future. Therefore, the researcher recommends for further expansion of similar designs in areas with high demand in order to empower more groups of informal workers, whether they are in Dodoma or elsewhere in Tanzania. Similarly, the researcher recommends that other ICT4D partners can apply similar low-cost technologies to support their business and expand their market niche in urban and sub-urban areas. The researcher suggest that provision of education to street traders and other informal workers on the significance of contextualized ICT-based projects is the

best approach for the success of information systems which aim to empower the marginalized groups in the country.

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