Mobile Application Framework for Collaborative Creation and Sharing of *Jua Kali* Product Designs:

A Case Study of Kamukunji Enterprise *Jua Kali* Cluster

James Njihia Gikera

Master of Science in Computer Based Information Systems

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Mobile Application Framework for Collaborative Creation and Sharing of *Jua Kali* Product Designs:

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James Njihia Gikera

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Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

James Njihia Gikera

..... [*Signature*]

..... [*Date*]

Approval

The dissertation of James Njihia Gikera was reviewed and approved by the following:

Prof. Ismail Ateya Lukandu (D.Sc.)
Faculty of Information Technology
Strathmore University

Dr. Joseph Orero
Dean, Faculty of Information Technology
Strathmore University

Associate Professor Ruth Kiraka
Dean, School of Graduate Studies
Strathmore University

Abstract

The informal *jua kali* sector is a vibrant entity that has created employment and innovative products in Kenya. Many homes in Kenya have at least one or more *jua kali* products. Over time, some products have evolved through incremental improvements to become award winning products. The *jiko* for instance has evolved into a number of fuel-conserving variants, some of which have garnered more merit than others. For instance, the *Jikokoa* and *Jiko poa* are highly polished ceramic types that have gained local and international acclaim. Both are patented trademarks produced by Burn Design Laboratories. However, not all *jua kali* products gain this kind of traction. The result is that many product designs are phased out naturally by demand and supply. The manual storage of product designs and sketches on paper is not reliable as they wear out, get lost or are stolen over time. Some artisans even prefer not to have any physical records of their designs for fear of duplication by others. This study therefore sought to propose the creation of a mobile application framework for collaborative creation and sharing of *jua kali* product designs to be used among artisans. The application allows direct sketches to be made on a smart device's touch screen and upload of images while helping track and attribute each contribution to the relevant artisan. This, the researcher hopes, helps in creating more customer-centric and uniform products with higher quality and less competing variations. The application has a user-interface and was designed as a web application to run on any internet enabled device with a web browser. The study utilized a mixed research methodology with both qualitative and quantitative data collection techniques. This enabled the researcher to understand the challenges and methods used and to analyze collected data in order to come up with the framework based on the results. 72% of the respondents indicated they would use the application to manage and store designs and sketches but only 36% would use it for collaborative creation citing lack of trust and exposure to risk as the main hindrance. This informed the researcher to create functionality for either doing private deigns or collaborating and sharing designs in a public domain. The objectives of this study were to identify the challenges associated with the current methods, review the existing online platforms, to develop a mobile application framework and to validate the mobile application framework for collaborative creation and sharing of *jua kali* products.

Dedication

To my loving wife-Lena, daughter-Louise, son-Jude, dad-Joel and both moms – named Loise. Thank you for your prayers and for putting up with me through the late nights and silent moments and for the laughter we share.

Acknowledgement

Thank you Almighty Father for your grace, gift of good health and sanity of mind during the course of my studies and research. Thank you Prof. Ismail Ateya, my immediate supervisor for the keen eye, honest critique and for pushing me outside my comfort zone throughout the dissertation process. Much gratitude to my lecturers for the knowledge passed on and positive criticism and my colleagues for the serious and fun moments in class and for the encouragement when I felt like calling it quits. We are friends now, and we made it!

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Definition of Terms

***Jua Kali* Artisan:**	A person who works in the *jua kali* sector.
***Jua Kali*:**	The direct translation of the words is 'hot sun' but the meaning refers to a very large number of hardworking and innovative entrepreneurs ("*Jua Kali* Intermediate Technology", 2016).
Jumia	Formerly known as Africa Internet Group (AIG), is an ecosystem of online commerces, marketplaces, classifieds, websites and applications created in 2012 and founded by Jeremy Hodara and Sacha Poignonnec ("Jumia", n.d.).
Natural Interfaces:	A structured approach to define and translate customer needs into workable plans to produce products that satisfy those needs (NPD Solutions, 2016).
TUIO:	An open framework that defines a common protocol and API for tangible multi-touch surfaces (Salvador-Herranz, Bañó, Contero, & Camba, 2014).

List of Abbreviations and Symbols

3D	-	Three-dimensional
CDE	-	Collaborative Development Environments
GDP	-	Gross Domestic Product
GoK	-	Government of Kenya
KIPI	-	Kenya Industrial Property Institute
SDLC	-	System Development Life Cycle
TUIO	-	Tangible User Interface Objects
UI	-	User Interface

Chapter 1: Introduction

1.1 Background

The informal *jua kali* sector is a vibrant and important part of the Kenyan economy. The products are affordable to many middle and lower class income families providing alternatives that are otherwise very expensive. However, unlike in the formal sector there is little collaboration in product design and improvement. The result is a multitude of similar looking products with varying designs, materials and shapes depending on the artisan's individual skills and tastes. Various platforms exist that attempt to fill in this gap.

JuaKali, an online platform, connects skilled workers to clients on demand. The platform provides an online environment where people have an opportunity to see the work that JuaKali workers can do. The creators aim at creating a culture of reliability and quality in the informal sector ("JuaKali Workforce Limited", 2015). On this platform a client can book a job online. A mobile application with the same name also exists.

Jua Kali information, another online platform aims at sharing information and feedback on hand tools, water harvesting, animal traction, transport, conservation agriculture among other hand tools. This platform enables downloading of simple drawings and information for items that are free of Intellectual Property Rights, deliberately done in black and white to keep the printing cost down ("*Jua Kali* Intermediate Technology", 2016).

However, these platforms fall short of covering the whole *jua kali* sector. The first is limited to eight specific *jua kali* work professions while the second is confined to agricultural and farming equipment. The ideal tool is a mobile application that is available to all artisans, can offer a personalized database for storage of designs and facilitate collaborative creation.

1.2 Problem Statement

Jua Kali entrepreneurs acquire most of their product design skills on the job either through training from an experienced artisan or by dismantling products and assembling them again (Kinyanjui, 2006). They therefore record a few if any of their new or modified designs with many preferring to memorize their designs for fear of theft and duplication. Whereas most products are easy to replicate, some are more specialized and take time to perfect. The few artisans that record their sketches and design specifications use manual storage in form of sketches on paper and photo albums. A good number of carpenters for instance prefer photo albums.

The artisans face a hard time learning new knowledge and trying to adapt to technology. Kinyanjui (2006) further says that cost of seeking knowledge and technology through self-initiatives, trial and error, frustrations and wastage of time and money, though not costed run into thousands of shillings. In line with the first objective, the researcher found out that this manual method of storage has a time-consuming effect as there were no records of step by step procedures, clear photos and design specifications to follow or for future reference.

An artisan can only learn a skill through training or replicating an existing product. This implies that the hard-earned knowledge would disappear with the artisan and the manual storage of designs on paper and photos can get worn out, stolen or lost. In addition, a customer who bought an item some time ago can neither trace the product nor the creator.

Successful applications created to run on mobile phones have positively impacted lives of the artisans. *Afya Poa* - an innovative mobile money-enabled micro health insurance and health savings product and *MBAO pension scheme* - established by the Kenya Jua Kali Co-operative Society Ltd as a retirement savings scheme. However, a gap still remains that shifts focus from the artisans to the products they make -a platform for collaborative creation and sharing of their product designs.

1.3 Research Objectives

i). To identify the challenges associated with the current methods and review the existing platforms used for collaborative creation and sharing of *jua kali* product designs.

ii). To develop a mobile application framework for collaborative creation and sharing of *jua kali* product designs.

iii). To validate the mobile application framework for collaborative creation and sharing of *jua kali* product designs.

1.4 Research Questions

i). What challenges are associated with the current methods and which are the existing platforms used for collaborative creation and sharing of *jua kali* product designs?

ii). How will the mobile application framework for collaborative creation and sharing of *jua kali* product designs be developed?

iii). How will the mobile application framework for collaborative creation and sharing of *jua kali* product designs be validated?

1.5 Justification

The *jua kali* artisans have no organized electronic method to their record product design specifications or share ideas. Artisans can copy, share and modify designs as they please. This results in too many variant products with similar designs but of varying materials and sizes. In addition a client may find it difficult to find an exact item purchased a while back as there are no clear records of design specifications and the creator.

However, a suitable mobile application allows creative collaboration that enables the artisan to record, share and store designs specifications while creating an online market for their products. This common platform enables shared knowledge, standardization and creation of better products. For clients, it is a remote platform to share ideas with artisans by providing a sketch or photo of a desired item and having the product made physically visiting the *jua kali* site.

1.6 Scope

The study was limited to developing a mobile application for individual and collaborative creation of *jua kali* products. Focus was on improving the processes, storage and management of jua product sketches and designs. In addition, attention was given to *jua kali* artisans and their clients. The study was conducted in the Kamukunji *jua kali* cluster within Nairobi County, near Machakos Country Bus terminus.

1.7 Limitations

1. The study was based on the assumption that the *jua kali* artisans have smartphones and are be capable of handling the application created as a collaborative tool for product design and improvement. The study was also based on the assumption that the representative interviews and samples taken during the study adequately represented the other *jua kali* clusters in Kenya.

Chapter 2: Literature Review

2.1 Introduction

The *jua kali* sector employs about eight million people in Kenya are directly or indirectly employed in the informal economy and it contributes about 18 % of the GDP (Kinyanjui, 2006). This is a huge number of workers whose contribution to the economy cannot be ignored. They are an important cog in the engine of development but they are faced by numerous challenges including technology and innovations gaps. They survive only by resilience through studying product designs of what is already in the market, replicating and modifying the same for the lower market.

2.2 *Jua Kali* Sector in Kenya

Out of the many *jua kali* clusters in Kenya, a majority are found in Nairobi, in area like Kibera, Kawangware and Parklands. Bull et al. (2014) explains that more than one third of the informal workforce is urban, with the densest concentration in Kenya's capital, Nairobi. Due to colonial-era segregation, most informal workers can be found in the Eastlands, an area where industry continues to expand.

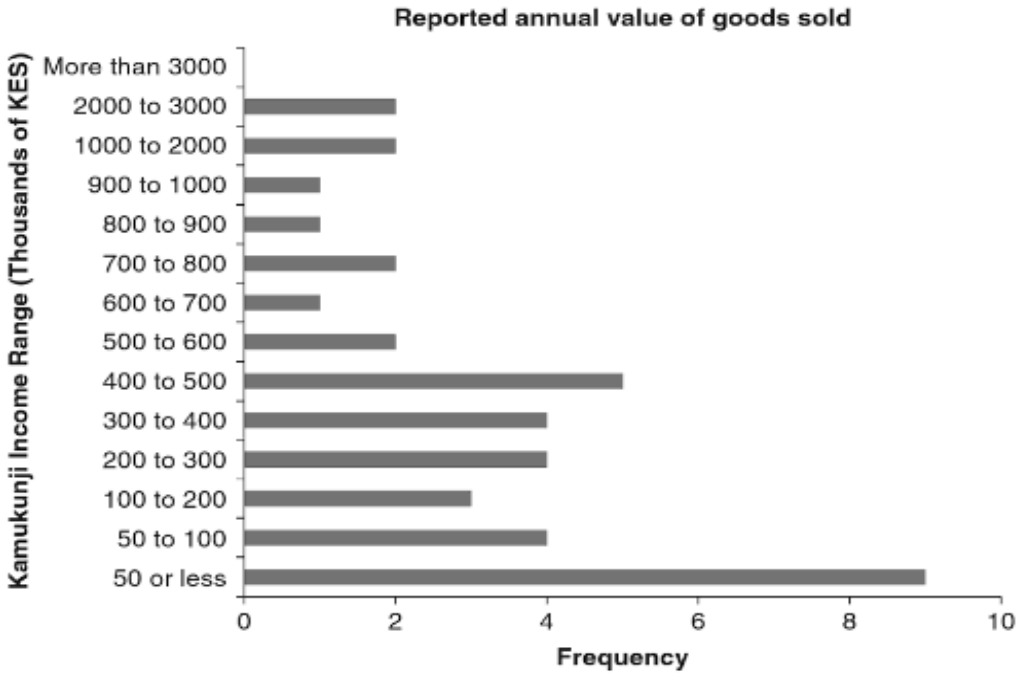


Figure 2.1: Annual value of goods sold reported by 40 firm owners in the Kamukunji cluster (Bull et al., 2014)

2.2.1 Kamukunji Jua Kali Enterprise Cluster

Kamukunji *Jua Kali* enterprise cluster is situated to the east of the Nairobi Central District and occupies about 10 hectares. It has a population of 5,000 artisans. The colonial government designated the area as a business centre for Africans suppliers (Kinyanjui, 2006). The main enterprise in this cluster is metalworking. Bull et al. (2014) cites that metalworking has been centralized in the Kamukunji *jua kali* cluster since Kenya's independence in 1963 due to proximity to the Machakos bus station which allows for easy distribution of products to the rest of the country

It evolved from a spontaneous settlement of a few metal workers and was recognized as a *jua kali* cluster in the 1980s. The co-location of micro and small enterprises in the cluster has facilitated the evolution of multiple transactions based on numerous relationships between entrepreneurs, brokers, traders and input suppliers (Kinyanjui, 2006).

Figure 2.2: Kamukunji cluster is outlined in red to the east (right) and Machakos bus terminus is outlined in red to the west (left) (Bull et al., 2014)

2.3 Challenges Faced by *Jua Kali* Artisans in Creation of Products

Even though the *jua kali* artisans constitute a huge chunk of the country's economy, they still face a lot of challenges that prevent their business from growing and life in general improving. Orwa (2007) stipulates that in Kenya, the millions of entrepreneurs and workers in the informal sector have long been disorganized and without a voice. This disorganization is clear even in the way the artisans design and

produce their products. There is little or no collaborative creation with individuals mainly working in clusters to mass-produce what has already been designed.

2.3.1 Recycling of Designs and Processes

Orwa (2007) asserts that for decades, the Kenyan Government and international organizations have devised programs to improve their situation, and yet neither their rights nor their economic opportunities have improved substantially one explanation for this stagnation is the reuse of the same old designs and processes in production. Little change has been observed in the way the *jua kali* artisans design and produce their products.

2.3.2 Patenting Intellectual Property

The Government of Kenya (GoK), through KIPI and under the Industrial Property Act, Cap. 509 provides clear guidelines on inventions and patenting. The term of patent protection is 20 years. This term is not renewable and once the term has expired, the invention is longer protected and can be exploited by anyone.

The law also requires the patent to be renewed every year for the entire duration of protection and if the patent is not renewed the rights lapse. To obtain a patent, one submits an application form to KIPI which is available from their website page. Patent protection is not automatic. One has to file an application with the patent office, who will in turn assess if the invention is still patentable (Patenting in Kenya, 2012).

2.3.3 Poor Knowledge of Laws and State Policies

Informal entrepreneurs generally do not know the laws and their rights (Orwa 2007). Consequently they are not well aware of technological opportunities available for them, and funds from government and other sources to pursue such ventures. The government –therefore stepped in and initiated the formation of Kamukunji *Jua Kali* Welfare Organization, a membership organization linked to the Kenya Federation of *Jua Kali* Association. Kinyanjui (2006) explain that platform was mainly created to encourage vertical joint action between the *jua kali* entrepreneurs such as buying land and also to serve as an avenue through which the government would communicate policies and interventions to *jua kali* entrepreneurs

2.3.4 Exploitation by Brokers and the More Enlightened Business Class

Kinyanjui (2006) asserts that the *jua kali* entrepreneurs exploit the position of co-location with other businesses as a marketing strategy and use onsite brokers to directly market customers to specific producers who for a commission. However these same brokers sometimes exploit them by overselling the product price and retaining some commission. Some middle and upper class well to do business people have hijacked ideas like the *jiko* to mass produce improved versions which have more consistent designs. They have better penetration and marketing power thus they are able to sell even in higher end markets like supermarkets robbing the artisans some clients.

2.3.5 Slow Accumulation of Technology

Kinyanjui (2006) explains that knowledge and technology does not come easy in the Kamukunji cluster. The road for accumulating and generating knowledge and technology for the *jua kali* entrepreneur is rough and tough. Most do not know the power of their mobile devices and only perceive it as a communication and transaction tool. They are not aware it can be a sketchpad, storage and management tool for their product designs.

2.3.6 Access to Finance Better Design Tools

In Kenya as well as in other East African countries banks regard business regulation as an important impediment to SME lending. The most common complaint has been cited as the Know Your Customer (KYC) aspect process imposed by most central banks is seen as too stringent for SMEs. A study carried out by the Financial Sector Deepening Kenya (FSD, 2008) , showed that SMEs face numerous hurdles in accessing finance, denying them an important growth line at best or accessing it at a very high cost. The Small and Micro Enterprises' (SMEs) access to finance is being constrained by exacting legal requirements by banks and other finance institutions, lack of a standardized and shared information registry and expensive and time consuming enforcement mechanisms (Magambo & Omwenga, 2015).

2.4 Current Methods used for Creation and Sharing of Product Designs

Most of the artisans in the *jua kali* industry are self-taught beginning with little knowledge and improving with time. Kinjanjui (2006) cites that Kamukunji *jua kali* entrepreneurs quickly observe new products in the market, study them and design methods of producing similar products or others that can serve the same purpose. She further notes that there is also a lot of knowledge sharing and innovators allow others to copy and adapt new technology. This flow of knowledge has enhanced the survival of the cluster.

2.5 Exiting Jua kali Online Platforms and Mobile Applications

2.5.1 JuaKali (juakali.co.ke)

The website connects skilled artisans to clients on demand. The platform provides an online environment where people have an opportunity to see the work that JuaKali workers can do. The creators aim at creating a culture of reliability and quality in the informal sector ("JuaKali Workforce Limited", 2015). On this platform a client can book a job online. A mobile application and a Facebook page with the same name also exist.

2.5.2 Jua Kali Information (juakali.info)

This is a website that enables *jua kali* artisans and other interested parties to share of information about a variety of tools including agricultural conservation, transport, animal traction and water harvesting among others. The sites has a display of photographs of the tools with accompanying descriptions. In addition, the pros and cons of each product are displayed. If their interest continues or intensifies and they wish to obtain an example, they can find manufacturing details including drawings for that product ("*Jua Kali* Intermediate Technology", 2016).

The information and drawings of the products are displayed in a simple way, with the latter being deliberately presented in black and white to reduce printing costs. The information and photos are downloadable and feedback is allowed. The site also encourages contributors with improvements or modifications and gives acknowledgment to the contributor. All items displayed are in public domain with none having any intellectual property rights granted or sought. The can be freely

copied and used as the user pleases, and as the site cites, for the betterment of mankind ("*Jua Kali* Intermediate Technology", 2016).

2.6 Collaborative Architecture Types

Isenberg, Elmqvist, Scholtz, Cernea and Ma (2011) states that using the space-time matrix, we can broadly categorize collaborative scenarios according to where they occur in space and in time. In space means they are either distributed or co-located while in time means they are either synchronous vs. asynchronous

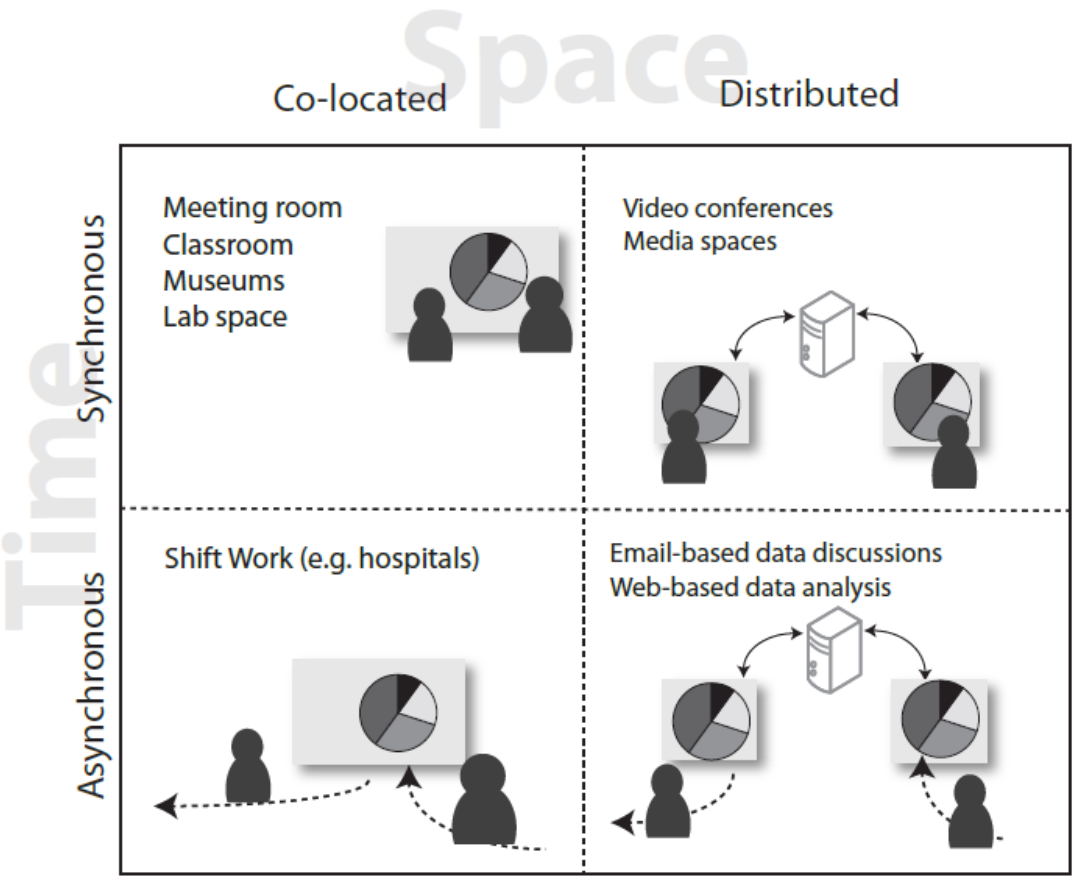


Figure 2.3: Collaborative visualization can occur in many scenarios delineated according to space and time (Isenberg, Elmqvist, Scholtz, Cernea, & Ma, 2011).

Table 1.1: Collaborative learning feature (Fatharani, Kusumo & Suwawi, 2016).

Collaborative Learning Feature	Supporting Tool
Synchronous tools	i. Audio Conferencing ii. Video Conference iii. Instant Messaging iv. Web Conferencing v. Chat vi. Whiteboards
Asynchronous tools	i. Discussion Board ii. Links iii. E-mail iv. Calendar v. Group Announcements vi. Surveys and polls
Document management	i. Resource Library ii. Upload/download

2.6.1 Synchronous / Real-time Groupware

Synchronous or real-time groupware allow geographically sparse users to interact in real time via shared computational resources. This differs with single-user systems, where there is no real-time interaction either between the people or the communication resources. With asynchronous groupware, interaction and object sharing is characterized by multi-user databases, and interaction is not immediate; and is instead a side-effect rather than a goal (Philips, 1999).

The intrinsic difficulty of producing groupware applications has led to a wide range of development approaches. Some of these are primarily architectural in nature: that is, they seek to make groupware simpler to develop by proposing and codifying structures appropriate to the problem domain. These codified structures are called architectures (Philips, 1999).

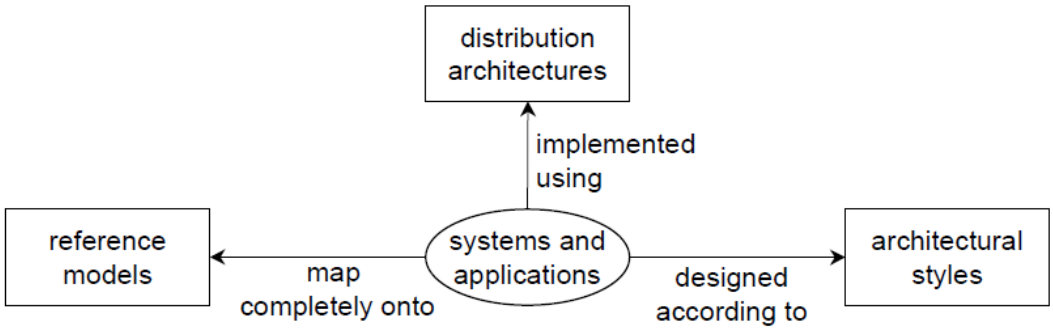


Figure 2.4: Relationships between the three architectural views and the systems and applications they model.

2.6.1.1 Reference model

Reference models specify the complete structure of some class of system at a relatively large granularity. This is typically done by creating a conceptual structure consisting of a small number of named functional elements and well defined data flow between those elements (Philips, 1999).

2.6.1.2 Architectural Styles

Architectural styles present a solution to a particular problem (in this case, how to develop synchronous groupware) in terms of a vocabulary of components, connectors, and the allowed relationships among them. Within the constraints imposed by the architectural style, a wide range of actual system configurations are possible. A system may be completely implemented in an architectural style, or a variety of styles can appear in the design of a single system (Philips, 1999).

2.6.1.3 Distribution Architectures

Groupware systems are necessarily distributed systems. Distribution architectures describe the run time distribution of system state and computation across computing platforms connected by a network. For example, a groupware application may be implemented entirely on a server with client/server communication at the level of window system events, or the application may be replicated at each user's location and the replicas kept in a consistent state using sophisticated consistency maintenance mechanisms (Philips, 1999).

2.6.2 Asynchronous Groupware

Email is by far the most common groupware application (besides of course, the traditional telephone). While the basic technology is designed to pass simple messages between two people, even relatively basic email systems today typically include interesting features for forwarding messages, filing messages, creating mailing groups, and attaching files with a message. Other features that have been explored include: automatic sorting and processing of messages, automatic routing, and structured communication (messages requiring certain information) (Finances Online, 2016)

Mailing lists and newsgroups are very similar to email systems, but the main difference is they are messages to groups of people instead of just one-to-one communication. Workflow systems on the other hand allow files or documents to be routed through groups or organizations using a relatively-fixed process. Workflow systems can provide interesting features including routing, development of various forms, and support for roles and privileges (Finances Online, 2016)

Group calendars allow you to schedule and manage projects, coordinate people, and will help you schedule deliverables or deadlines. Typical features of a group calendar include: detection of conflicting schedules and coordination of meeting schedules that can work for everyone. Group calendars can help you to locate people, too (Finances Online, 2016)

2.7 Collaborative Systems

Collaborative software architecture is based on distributed systems. That includes a server application, client application and a database server. Collaborative systems comprise collaborative software, hardware and all the required personnel. So, testing is done for these dimensions: software, hardware and people. Evaluation of personnel involved in collaborative systems could take into account the education level; certification level; social abilities; experience; team homogeneity degree and work productivity (Pocatilu & Ciurea, 2009).

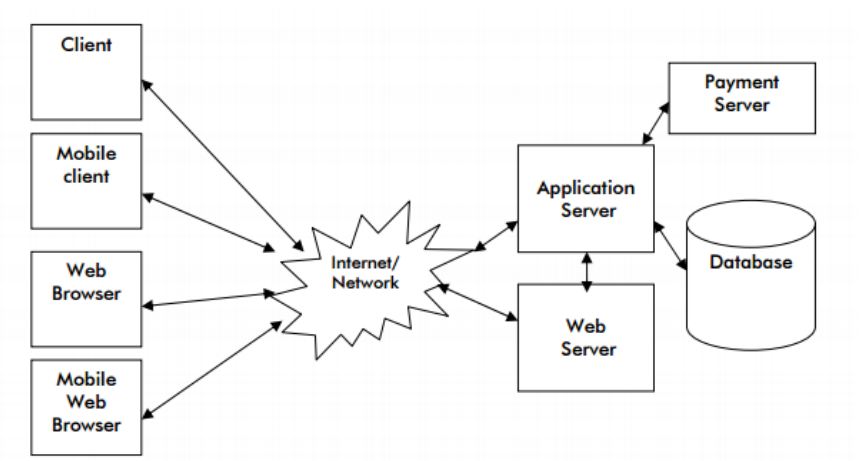


Figure 2.5: Architecture of a collaborative system (Pocatilu & Ciurea, 2009)

2.7.1 Classification of Collaborative Systems

Collaborative systems are classified in: collaborative functional systems, collaborative micropayment systems, collaborative planning systems, collaborative tagging systems, collaborative writing systems, and collaborative medical systems. (Pocatilu & Ciurea, 2009).

Figure 2.6: Architecture of a collaborative micropayment system (Pocatilu & Ciurea, 2009)

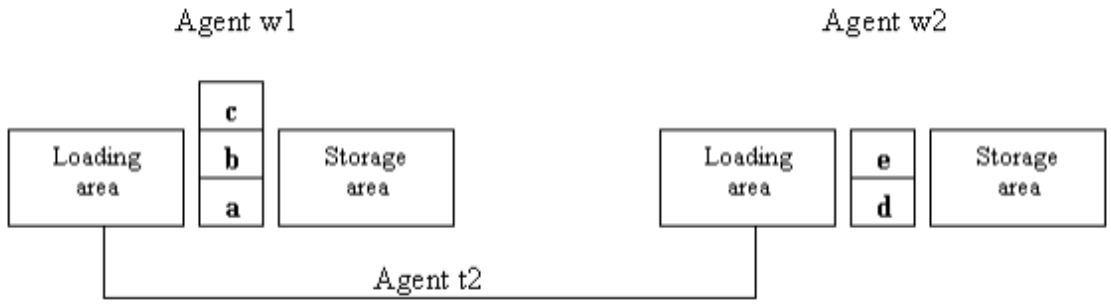


Figure 2.7: Example of collaborative planning system (Pocatilu & Ciurea, 2009).

2.7.2 Collaborative Software Testing

Software testing is the process of finding errors in software. There are two main strategies for software testing: white box testing (structural testing) and black box testing (functional testing). Testing collaborative software, as Internet application, requires the following type of testing: functional testing, compatibility testing, content testing, performance testing, load testing, security testing, Web server testing, application server testing and database testing. Unit testing, integration testing and regression testing need to take place during system development in order to assure high quality software (Pocatilu & Ciurea, 2009).

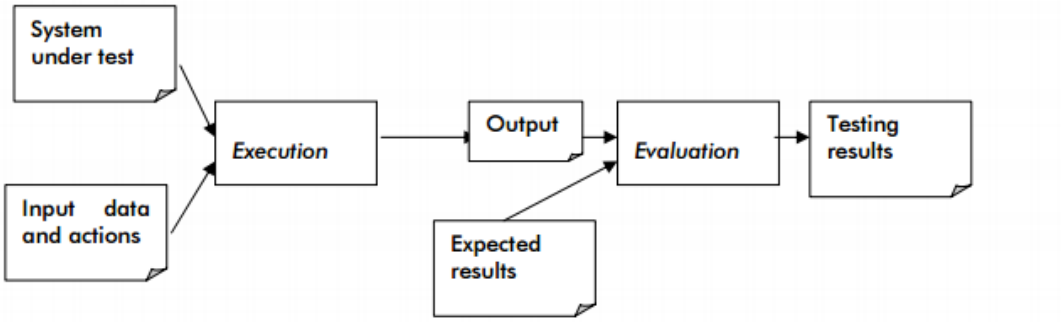


Figure 2.8: Functional system testing (Pocatilu & Ciurea, 2009).

2.8 Examples of Collaborative Systems

2.8.1 Tabletop System

In a local collaborative design scenario, tabletop systems provide a large interactive and tactile surface around which team members can gather, interact collaboratively with the system, and communicate in face-to-face discussions. In an extended local collaborative scenario where some members of the team are dispersed, users with tablet or desktop computers can share a virtual common workspace in real time and use videoconferencing applications to simulate the face-to-face communication environment (Salvador-Herranz, Bañó, Contero, & Camba, 2014).

These devices provide a large multi-touch interactive surface that can be combined with natural interfaces, allowing simple interaction with the surface using hand and finger gestures. The software component of our system was developed using the game engine Unity3D, which is multiplatform, ensuring it can run on

different hardware (tablet computers, tabletops, interactive surfaces, and desktop computers) and operating systems. To maximize compatibility with different types of input devices, our application supports the standard TUIO (Salvador-Herranz, Bañó, Contero, & Camba, 2014).

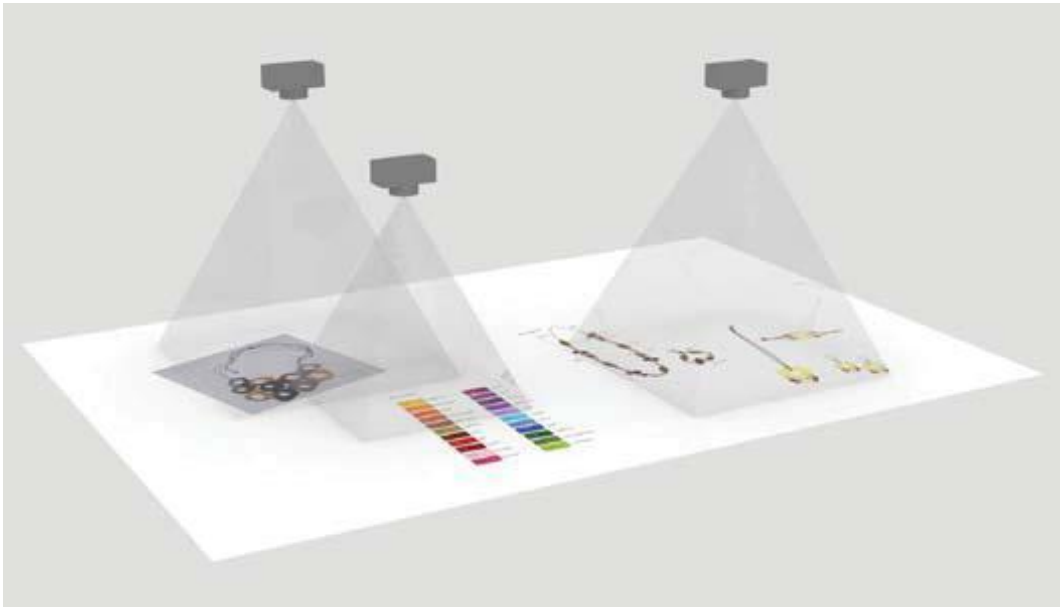


Figure 2.9: Virtual cameras associated with three client devices (Salvador-Herranz, Bañó, Contero, & Camba, 2014)

Collaborative interaction is not limited to members of the same team. Teams can also interact with each other. In a local setting, members of a team can walk around the room, talk, and share their work with other teams. With our tool, this form of collaboration is managed by simulating a large surface with multiple workspaces arranged separately by team. The large area reinforces the idea of Interactive Space and represents a common workspace independent from the teams' locations. Teams decide how this large workspace is organized and are allowed to work privately on any area of the surface, or share their work collaboratively with other teams. The information exchange and synchronization is based on cloud computing concepts. (Salvador-Herranz, Bañó, Contero, & Camba, 2014).

Figure 2.10: Member of a design team working on the project with a tabletop (Salvador-Herranz, Bañó, Contero, & Camba, 2014)

2.8.2 Calico - Collaborative Sketch Design Tool

In a design studio, instructors provide guidance in the moment of working, rather than simply evaluating a separately created final product of the students' work. Students learn how to reflect on their experiences, collaborate within teams, and learn from one another, all under the guidance of an experienced instructor. Studies have reported effective results in using design studios to provide students with opportunities to put the knowledge gained from lectures into practice (Loksa, Nicolas, LaToza, & André van der, 2013).

Using Calico to bring separate work together seemed, in most respects, to be second nature to the students. As one might lay out pieces of paper in front of oneself, the students naturally used the grid view to review designs at a bird's eye view. When designing, inspiration may come from many sources, including the comments and actions of other designers. Working in a studio setting within a group may then afford students a greater opportunity to find inspiration (Loksa, Nicolas, LaToza, & André van der, 2013).

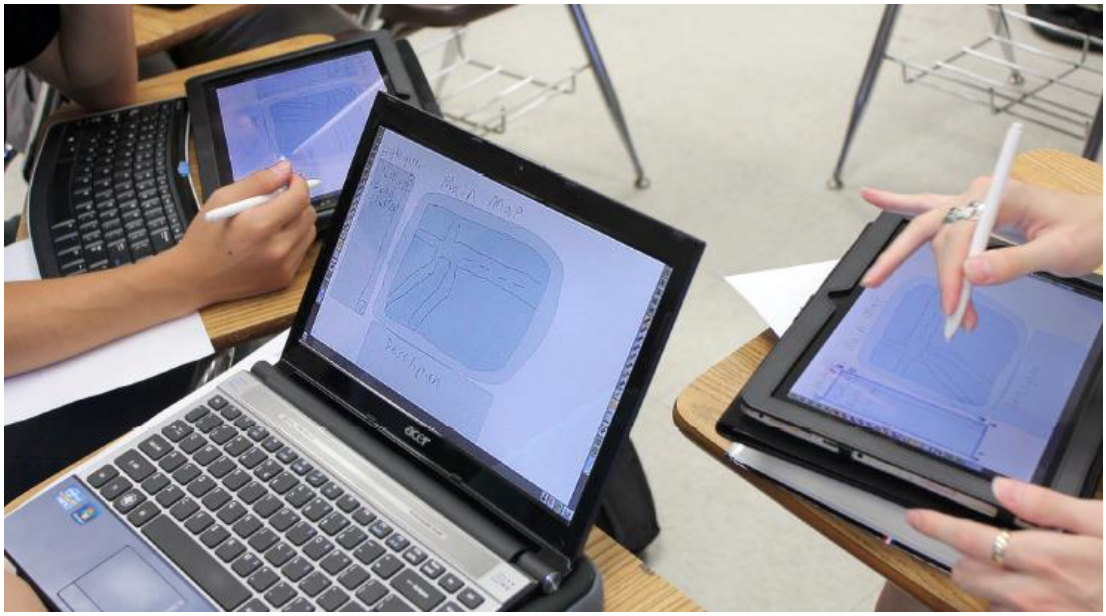


Figure 2.11: Students use interface sketching to facilitate brainstorming (Loksa, Nicolas, LaToza, & André van der, 2013)

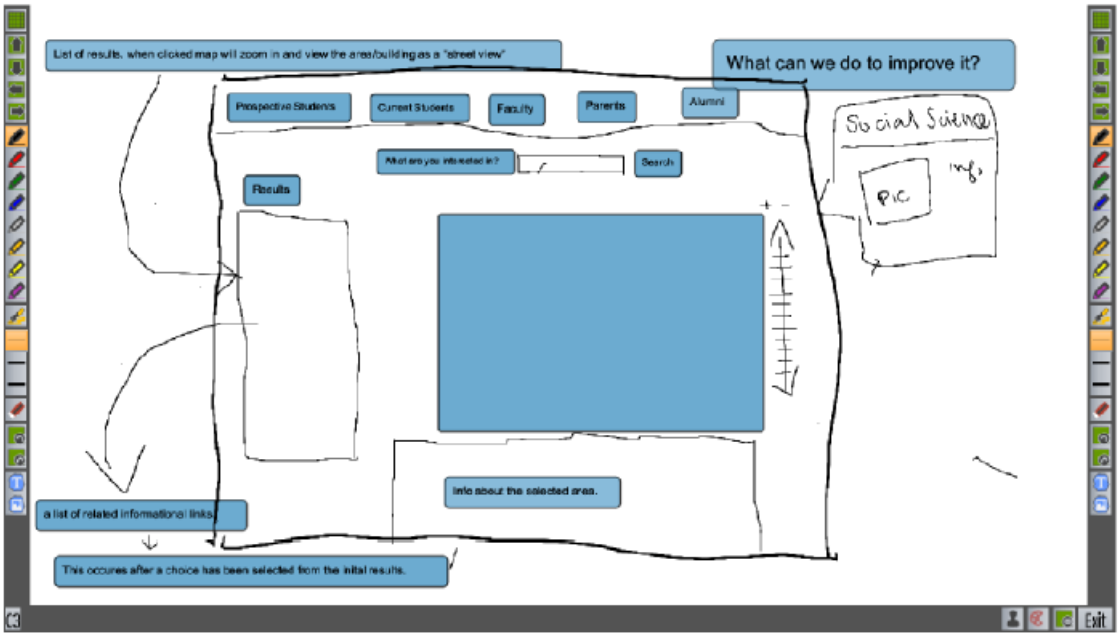


Figure 2.12: Students using text scraps and sketches to design a user interface layout (Loksa, Nicolas, LaToza, & André van der, 2013).

2.9 Collaborative Development Environments

Collaborative Development Environments (CDE) gives a project workspace with a standardized tool set to offer a frictionless development environment to

increase developer comfort and productivity. Several CDEs are available as commercial products or open source initiatives—increasingly, as online services hosted externally.

Table 2.1: Collaborative development environments (Lanubile, Ebert, Prikladnicki, & Vizcaíno, 2010)

Collaborative development environments

	Collaborative development tools						
CDE	**Version-control systems**	**Trackers**	**Build tools**	**Modelers**	**Knowledge centers**	**Communication tools**	**Web 2.0 applications**
SourceForge (sourceforge.net)	CVS,* SVN, Git, Mercurial, Bazaar**	Bugs, feature requests, patches, support requests	No	No	No	Mailing lists; forums	Feeds; hosted applications for blogs, microblogs and wikis
GForge (gforge.org)	CVS, SVN, Perforce†	Tasks and issues (bugs, feature requests, patches, support requests)	Integrating CruiseControl	No	Document manager	Mailing lists; forums	Feeds, wiki
Trac (trac.edgewall.org)	SVN; plug-ins for integrating Git, Perforce, Mercurial, Darcs, Bazaar	Tickets (tasks, feature requests, bugs, support issues)	Bitten plug-ins for integrating: Continuum, CruiseControl, Hudson‡	Project roadmap	As wiki	Plug-in for forums	Wiki, feeds, plug-ins for tagging tickets and wiki pages
Google Code (code.google.com)	SVN, Mercurial; integrating Git	Issues (defects, enhancements, tasks)	No	No	As wiki	Integrating Google Groups	Wiki, feeds
Assembla (www.assembla.com)	SVN, Git, Mercurial	Tickets (tasks, enhancements, ideas, defects)	No	Milestones, agile planner	As wiki	Message board, chat	Wiki, microblog, feeds
Rational Team Concert (jazz.net/projects/rational-team-concert)	Built-in	Work items (defects, enhancements, plan items, retrospectives, risk, stories, tasks, build items, use cases)	Built; integrating Ant,§ Maven	Process templates	Integrating MS SharePoint and Lotus Quickr document	Instant messaging	Feeds, wiki, tagging work items
GitHub (github.com)	Git	Issues	No	No	As wiki	No	Feeds, wiki, social networks
Launchpad (launchpad.net)	Bazaar	Bugs; integrating with external trackers	No	Blueprints (specifications of features or processes)	Questions and answers	Mailing lists	No
CodePlex (www.codeplex.com)	Built-in	Work items (features, issues, tasks)	CruiseControl.NET	Documentation tab	As wiki	Mailing lists, discussions list	Feeds, wiki

2.10 Conceptual Design

Figure 2.13 shows the conceptual design of the application. A user logs into their profile via their mobile device, they find a main menu with options for creating a new sketch, uploading an image or viewing existing images. Design sketches and images are stored under project names and have accompanying product specifications. Stored designs (sketches and images) can be retrieved via their project names.

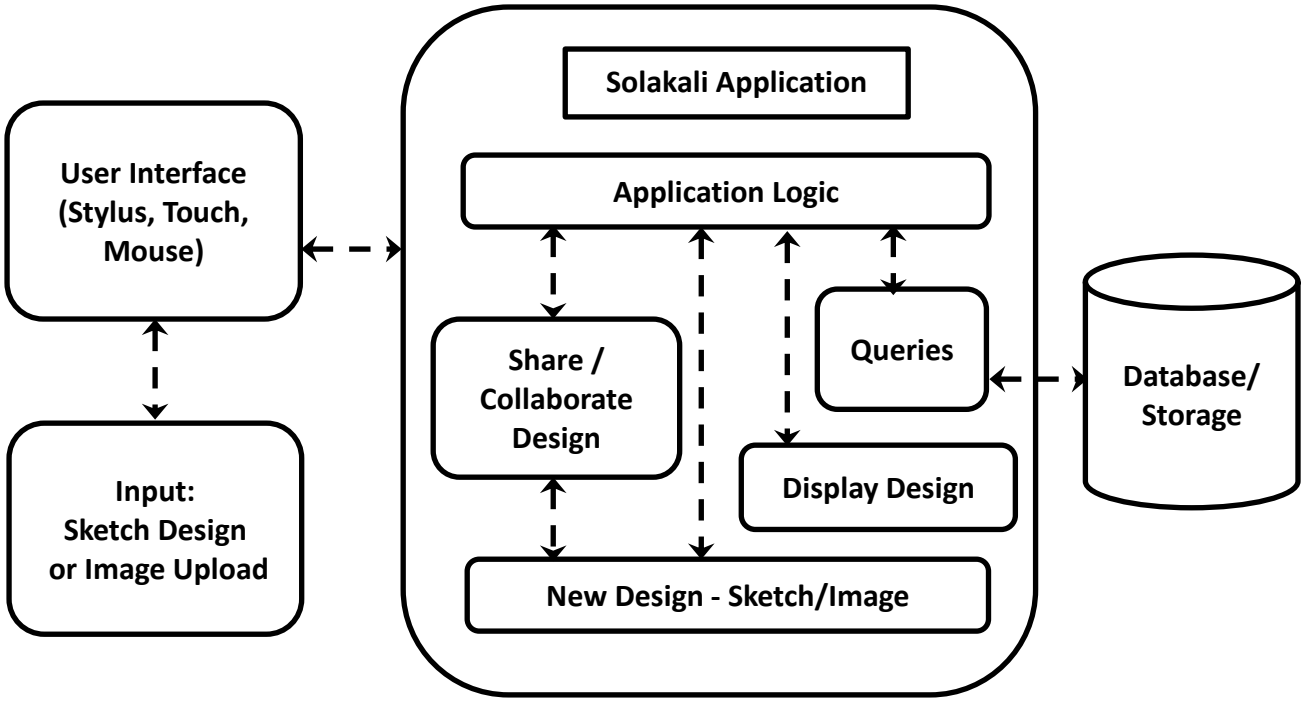


Figure 2.13: Conceptual Design of the Mobile Application Framework

2.11 Summary

The *Jua kali* industry is an "open source" market, where the artisans thrive by copying, sharing and modifying designs through peer networks. Kinyanjui (2006) says together, peer entrepreneurs' design and make products similar to those made in formal enterprises, imported or those brought in by customers. These peer networks evolve after long periods of association and facilitate informal joint action in the cluster. The peer networks, which define the rules and regulations of learning, are both real and virtual.

The designs that are created and modified over time are mainly handed over by word of mouth and mainly exist in the memories of people, backed by paper and photo storage either in physical or digital albums. There is existing collaborative creation tool for the artisans to share designs and improvements on products, or for clients to share their ideas of original or improved products.

From the findings of this study, the researcher sought to develop a mobile application that allowed direct sketches on the mobile device surface, upload of photos and organized storage of the uploaded images with their design specifications and owner identities. The application was also to allow printing and off-site backup in case of phone damage or loss.

Chapter 3: Research Methodology

3.1 Introduction

Research methodology is way of systematically solving the research problem. (Kothari, 2004). It can be considered as the science of doing research (Bhatnagar & Singh, 2013), with the aim of releasing the objectives that the researcher had set to achieve by the end of the study. Research design, target population, sampling procedures, design approach, data collection and analysis are discussed. In addition, the validity, reliability and ethical considerations of the research are also discussed. A mixed research method with both qualitative and quantitative data collection techniques was used in the study.

3.2 Research Design

Jabar, Sidi, Ghani and Ibrahim (2009) state that according to Clark (1997), research conducted within the computer science and engineering involves the conception, design and development of in information system using information technology. The new technology is designed to intervene in some setting, or to enable some function to be performed, or some aim to be realized.

The goal of this research is to first find out the challenges *jua kali* artisans face while creating designs either individually or collaboratively as groups. The second is to review the methods they are currently using in creating those designs to attain the second objective. Lastly, it is to come up with an application that can helps resolve the identified challenges while improving on the existing methods in line with the third objective. The success of the application was determined by testing and validating the application to meet the final objective.

3.3 Location of Study

The research was conducted in the Kamukunji *Jua Kali* Cluster in Nairobi County where majority of the artisans engage in metalwork. The location was chosen for its metropolitan and inclusive nature, being in the capital city and near the busy Machakos Bus terminus. Proximity and time constraints were also considered for ease of movement during research. Alternatives are other *jua kali* open air markets and clusters in Nairobi which include Kawangware, Kibera and Embakasi.

The researcher in interested in finding the artisans and clients in their natural setting to gather information. The focus of the research was to get a way to systematically solve the research problem defined using applied research (Kothari, 2004). It was of paramount importance that the researcher was able to understand the methods used before the application and what they desired of a new creative collaboration mobile application.

3.4 Target Population

Kothari (2004) describes a population as the sum of all items under consideration that take part in a research. The respondents for this research form part of the larger population of *jua kali* artisans in the Kamukunji *jua kali* cluster. The target population also included images of *jua kali* products and designs either captured directly from the field or downloaded from the internet.

3.5 Sampling Procedures and Sample Size

3.5.1 Sampling Procedure

Simple random sampling was used to get respondents from the population of *jua kali* artisans. Mugenda and Mugenda (2003) state that this method is used where each member of the target population has an equal probability of being chosen to be included in the sample.

3.5.2 Determination of the Sample Size

In this study, the researcher targeted a sample size of 50 artisans from the cluster thus interviewed 58 artisans. Mugenda and Mugenda (2003) recommended a sample size of 384 individuals when the population is more than 10,000 and the following formula $nf = n/ (1 + n/N)$ when the population is less than 10,000 individuals.

Where

nf = the desired sample size when population is less than 10,000

n = the desired sample size when population is more than 10,000

N = estimate of the population size.

Therefore applying the formula, the sample size (nf) was 384/ (1+384/58) = 50

3.6 Data Collection Methods

In this research, qualitative data was collected through face to face guided oral interviews. This was important in identifying the current methods used in individual and collaborative creation of *jua kali* product designs in line with the first objective.

3.6.1 Interviews

The researcher collected qualitative using oral guided interviews. Open and closed ended questions were asked and answers recorded on an individual level. This face-to-face approach allowed the researcher to establish a rapport with the respondents thus got more in-depth information, covered more ground quickly and obtained visual cues.

3.6.2 Secondary Data

Literature review was used to collect secondary data. This allowed the researcher to find out similar projects carried out in Kenya as well as on other informal sectors worldwide where collaborative creative tools have been successfully or otherwise employed. This approach aided the researcher to gain knowledge on the existing gaps and loopholes that can be amended while developing the new application, while adopting the ideas to suit the local *jua kali* setup.

3.7 Data Analysis and Presentation

3.7.1 Data Analysis

Data collected on site from the oral interviews was from a single major group of respondents, the *jua kali* artisans. Data cleaning was achieved by removing incomplete, incomprehensible and error-containing data to prevent problems arising during data entry. Analysis was done using both qualitative and quantitative data analysis techniques. Qualitative data was collected from face to face interviews, behavioral observation during the testing phase and general reactions of the artisans in their natural environment. This was used to complement the quantitative data. Quantitative data was analyzed using comparative tables which were prepared to summarize the responses in numerical form and presented in percentages. This tabulation enabled clear representation and easy analysis of the. Analysis was done soon after collection to minimize errors and loss of collected material thus maximizing the findings.

3.7.2 Data Presentation

The analyzed data was presented using tables. Data flow diagrams were also used to aid in providing an in-depth flow of the processes involved for the system. Entity relationship diagrams were used to show relations between various entities.

3.8 System Design and Development

The Systems Development Life Cycle (SDLC) is a phased approach to analysis and design that holds that systems are best developed through the use of a specific cycle of analyst and user activities (Kendall & Kendall, 2011). The researcher utilized this approach in the study from the inception of the idea to the completion of the working application.

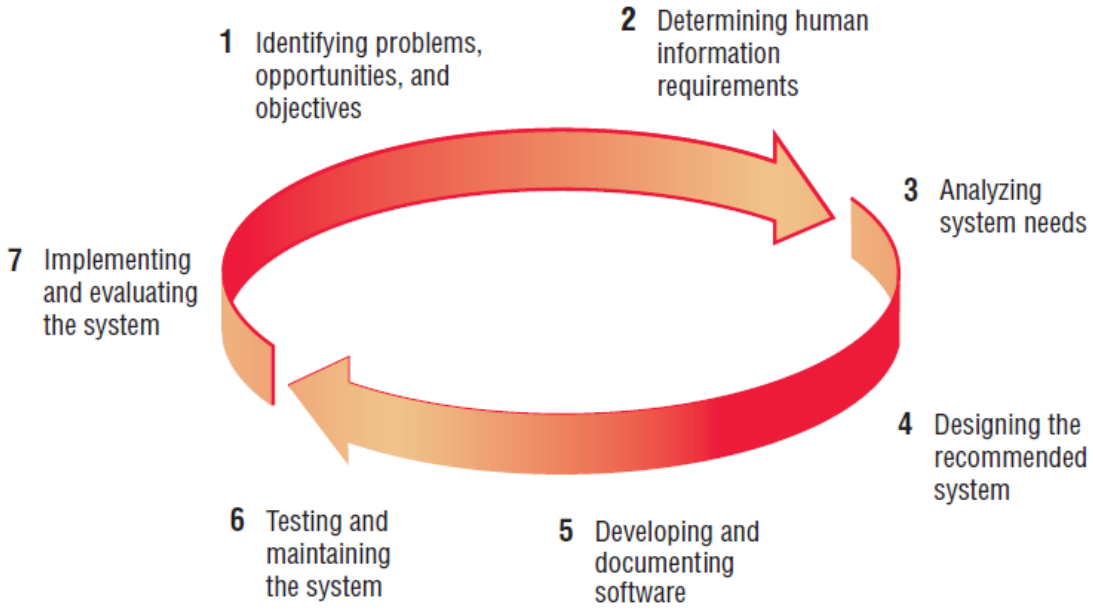


Figure 3.1: The seven phases of the systems development life cycle (SDLC) (Kendall & Kendall, 2011).

In the first phase of the cycle, the researcher, in line with the first objective, aimed to identify the challenges associated with the current methods used for collaborative creation and sharing of jua kali product designs and which opportunities would arise to eliminate them. From the research findings, these challenges include lack of ownership of smartphones, with only 48% owning them, lack trust in collaboration with 64% citing they would not use it for collaboration but 72% would use the app to manage and store their designs. The opportunity thus was

creating an application that would inhibit exposing private designs while allowing sharing only what the user wants and providing a secure storage while helping manage the designs.

In the second phase, the researcher conducted face to face guided oral interviews while oberving the artisans' behaviour in their natural setting in a non-unobtrusive manner. In addition sampling of existing designs and actul products was conducted. In the third phase the reseracher used sequence diagrams to show the flow od evebts, data flow diagrams (DFD) to chart the inputs, processes, and outputs, and tables to aid summarise and analyse quanititave data.

In the fourth phase, the researcher adapted the agile development process to gradually improve the the application framework. This was aided by following the diagramatic representations develped in the third phase. This ensured proper flow and ineraction of the different components of the system, from the interface, theough the code to the database.

In the fifth phase, the researcher came up with a step by step manual for user registration, login and basic navigation through the application. In addition, the reseracher took actual snapshots of the application interface for ease of learning the application with accompanying explanations. In the last stage, the researcher tested the accuracy of the system using different devices (Laptop, tablet, smartphone) with varying input devices (Mouse, stylus, touch-finger) then further tested the application with a group of artisans to test the accuracy of sketches made.

3.9 System Development Process

The researcher utilized agile development to eliminate excess modeling and documentation and instead encourage face-to-face communication. Dennis, Roth and Wixom (2012) state that a project emphasizes simple, iterative application development in which every iteration is a complete software project, including planning, requirements analysis, design, coding, testing, and documentation.

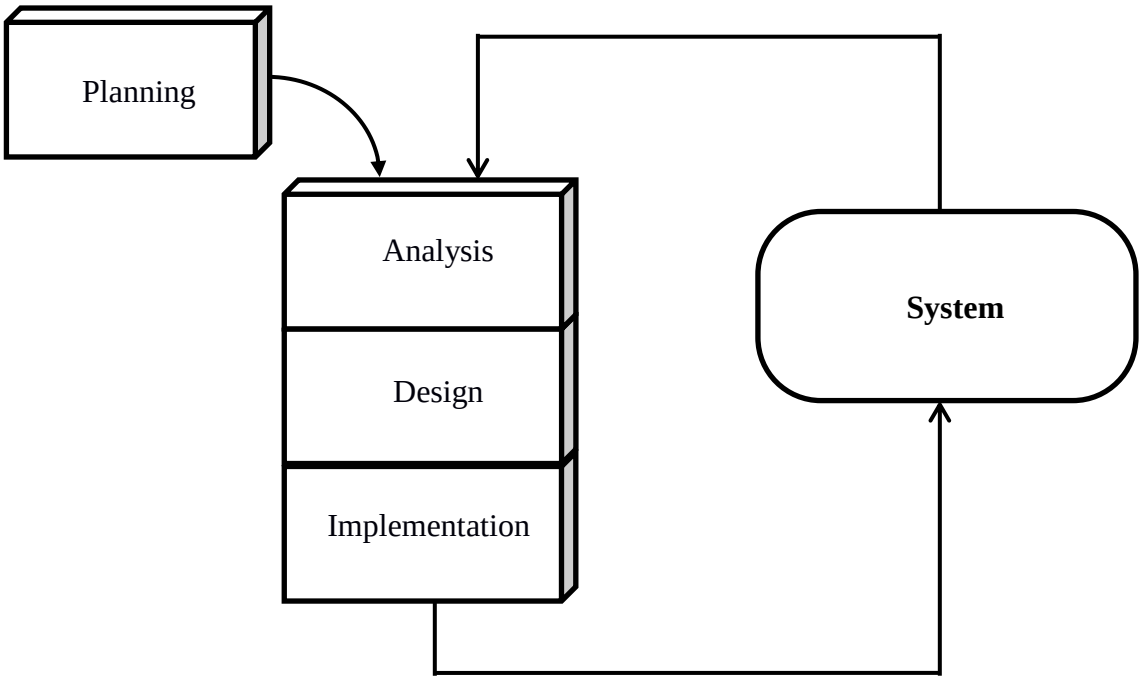


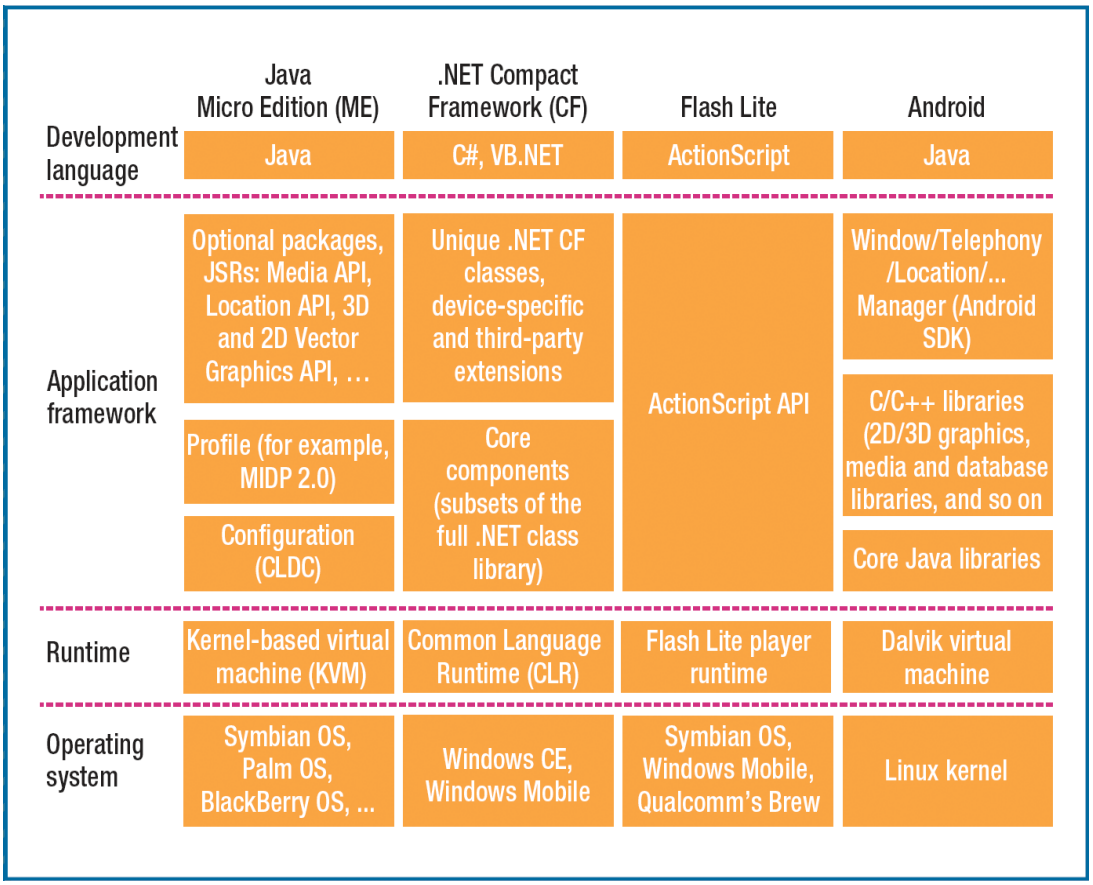
Figure 3.2: Agile Development (Dennis, Roth & Wixom 2012).

3.9.1 Software Development Process

Software development has shifted focus from companies meeting targets to being more customer-centric. In the line mobile devices are increasingly accepted as suitable media for multimedia-rich applications. Software firms have started promoting programming platforms and tools tailored to satisfy the requirements of mobile device users, developers, and resource constraints (Economou & Gavalas, 2011). This makes them the perfect tool for the researcher's application.

The researcher developed the "*SolaKali*" system to run as a web application and runs on any mobile device that supports internet connectivity. The system can run on different browsers including Mozilla's Firefox, Microsoft's Internet Explorer and Google's Chrome. The application was developed using PHP and HTML with an SQL database for data storage and management.

Table 3.1: Comparison of operating systems, runtimes, application frameworks, and development, (Economou & Gavalas, 2011).



3.10 Validity and Reliability of the Research

Joppe (2000) defines reliability as: "The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable." (As cited in Nahid, 2003). The researcher achieved this by testing the application severally on different browsers and devices with different groups of people.

3.11 Ethical Considerations

The researcher explained in detail the purpose of the research before embarking on the survey. The interview guide was developed and interviews conducted in a way that ensured respondents answered comfortably and truthfully. Utmost confidentiality was maintained and the respondents' names were not recorded. All borrowed works are cited appropriately and acknowledged to the respective authors.

Chapter 4: System Design and Architecture

4.1 Introduction

Evaluation of the design and architecture of the proposed system was done by factoring in the requirements collected from potential users and ability to function as fully expected. To attain this, diagrammatic representations were created using modelling software to bring out detailed understanding of each element. These are data flow diagrams and use case diagrams with descriptions. The diagrams show how data is relayed from the user interface to the database and how different users interact with the application.

4.2 Requirements Analysis

This section focuses on the requirements that the researcher attained, based on the objectives of the study and the data collected from users.

4.2.1 Usability

The application has a simple and user friendly interface.

4.2.2 Compatibility

The application is supported by any smartphone that can run web applications and can connect to the internet.

4.2.3 Functionality

i. The application supports screen touch functionality to allow sketching and drawing on the screen surface.
ii. The application allows upload of text in the acceptable formats: .DOC, .DOCX, .PDF and .TXT.
iii. The application allows upload of images up to a file size of 15 MB in the acceptable formats: .JPG, .JPEG, .PNG, .GIF and .TIFF
iv. The application supports creative collaboration between registered users.

4.2.4 Reliability

i. The application is able to store uploaded pictures
ii. The application is able to automatically sync offline data to an online database and be able to restore lost files to user's device.

4.3 System Architecture

The architectural design is illustrated in Figure 4.1. The user begins by logging into the application via a browser on a mobile client. This can be a mobile phone, a tablet or a laptop. New users have to register first. Once logged in the user finds a menu where they can either access their private or public designs. They are able to add a new or edit an existing design project that is either private or is open for editing in the public domain. Private designs are accessible only to the user while public designs are accessible to all users. The designs are stored locally in the user's device and backed up periodically onto a cloud server. When the user sketches or uploads a photo of an item or a design, the captured image is stored under a project number, name and owner number.

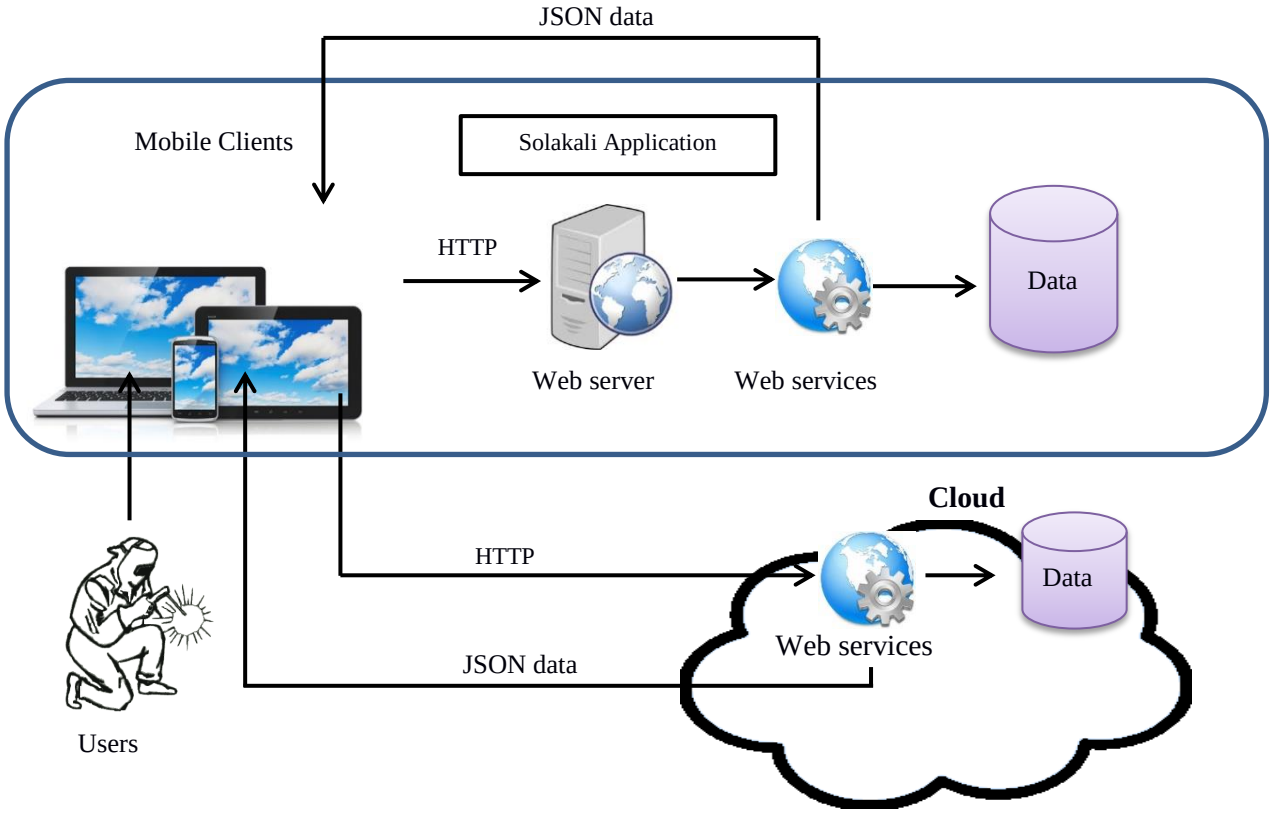


Figure 4.1: System Architecture Design

4.4 Diagrammatic Representation of Tool

4.4.1 Use Case Description

There are three key actors namely the user, the guest and the system administrator. A user is a registered artisan or client who by being registered can view and share or collaborate in a design. A guest is an unregistered artisan or client who can only view designs from the public domain. They cannot share or edit designs thus act as passive viewers. There are six use cases namely view public designs, edit public designs, edit private designs, manage users, manage designs and manage social media. Each of the use cases represent an action point in the use case diagram and the sequence of events therein from the interaction of the actors and the system.

Table 4.1: View Public Designs use case

Use Case:	**View Public Designs**
Primary Actor	Guest
Pre-condition	Unregistered or registered Artisan / Client
Post condition	View designs in public domain

Actor	**System**
1. User accesses main menu	
	2. System displays Main Menu
3. User chooses Public Designs	
	4. System displays Public Designs

Other use case tables are illustrated in Appendix D.

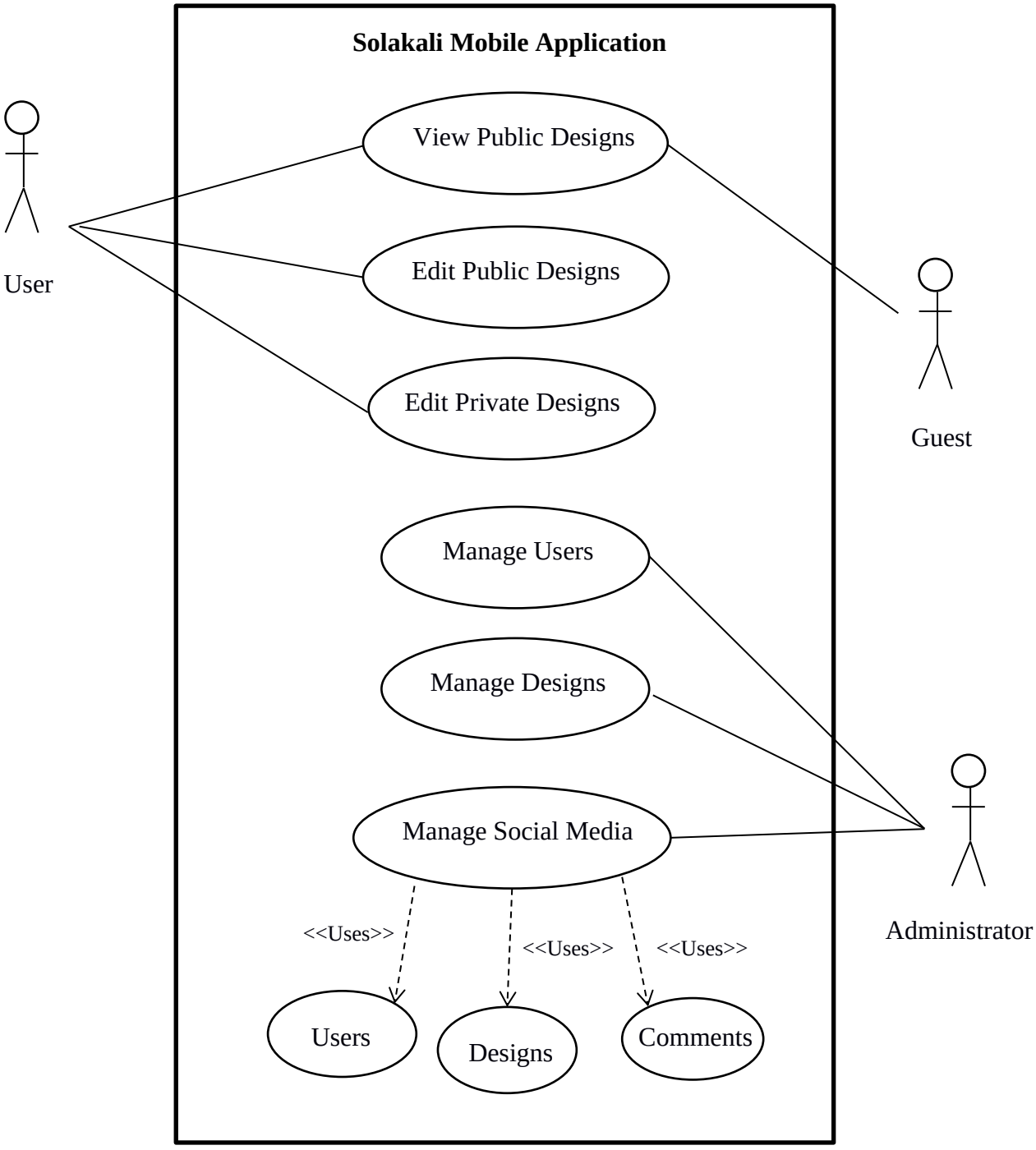


Figure 4.2: Use Case Diagram

4.4.2 Entity-Relationship Model

Figure 4.3 visually depicts the various entities of the proposed system. This is achieved by used of class diagrams which enable illustration of real-world objects. The model shows the attributes of each class and that allow communication between the classes via requests. These class associations are shown from the time the artisan sketches or uploads an image to the time of collaboration. The system is tested via set of selected sketches and diagrams which act as test data to verify it is working as expected. The administrator manages the content to reduce errors.

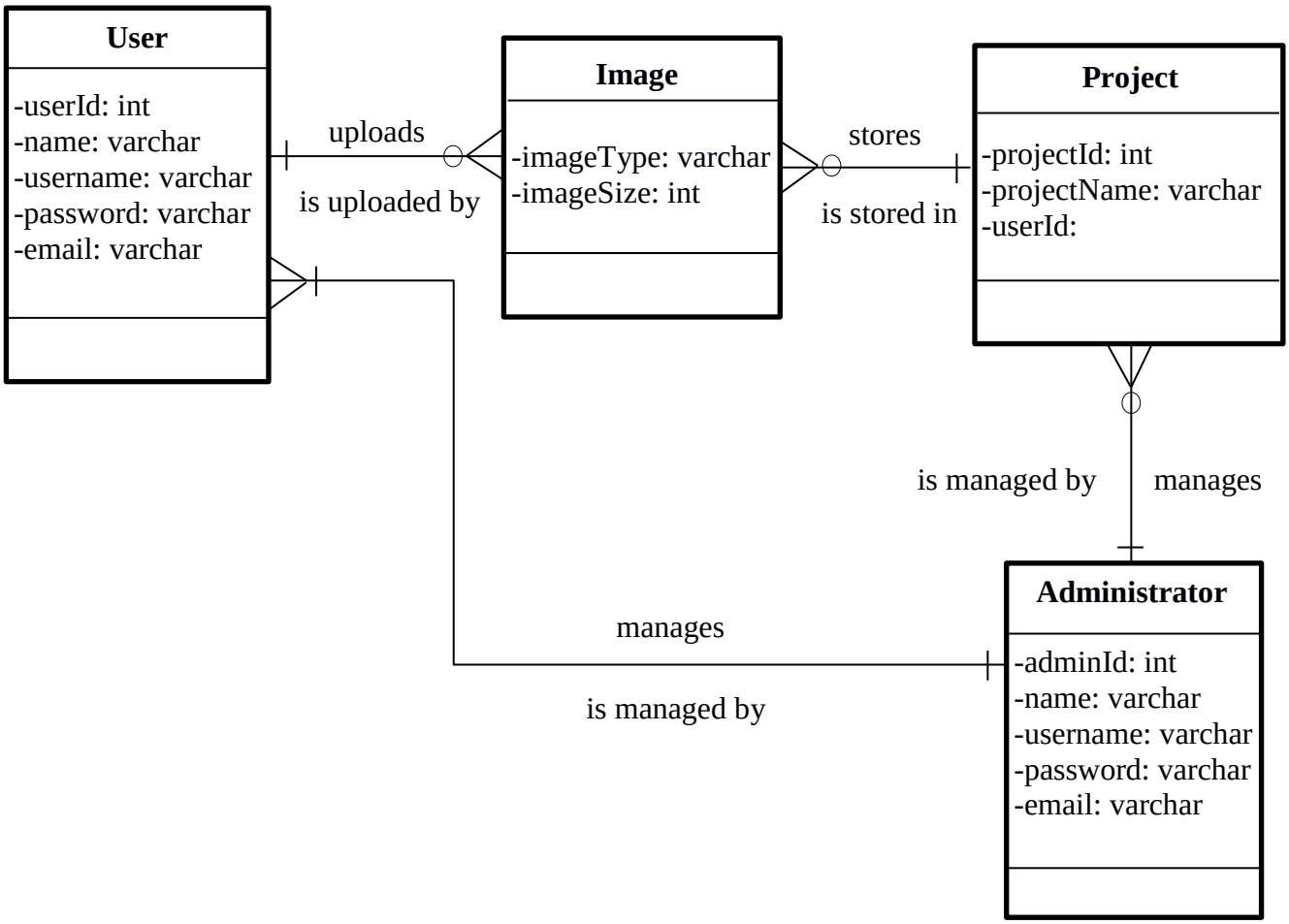


Figure 4.3: Entity Relationship Diagram

4.5 Activity Diagram

Figure 4.4 shows the control flow of the system activities in sequence. The initial activity is input of the sketch of diagram whose format and size are verified. The image then has to be stored in either the public or private designs. At the end the finished design is displayed in the dashboard.

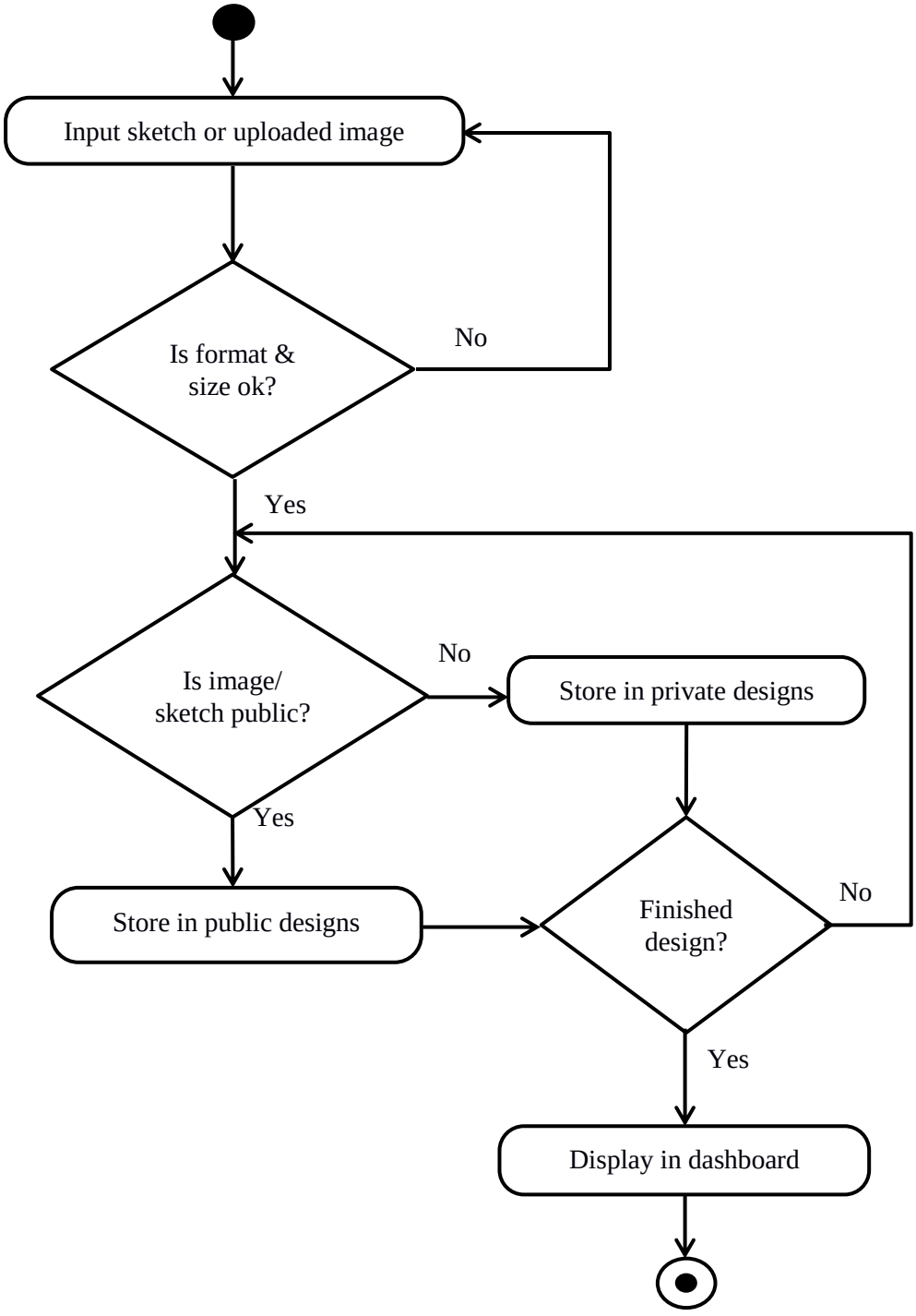


Figure 4.4: Activity Diagram

4.6 Sequence Diagram

Figure 4.5 shows the flow on activities in sequence. The artisan sketches or uploads an image, the image format is checked. If ok the image size is checked. If ok the image is stored under the respective category, private or public designs. The image can then be viewed by users and guests depending on access level.

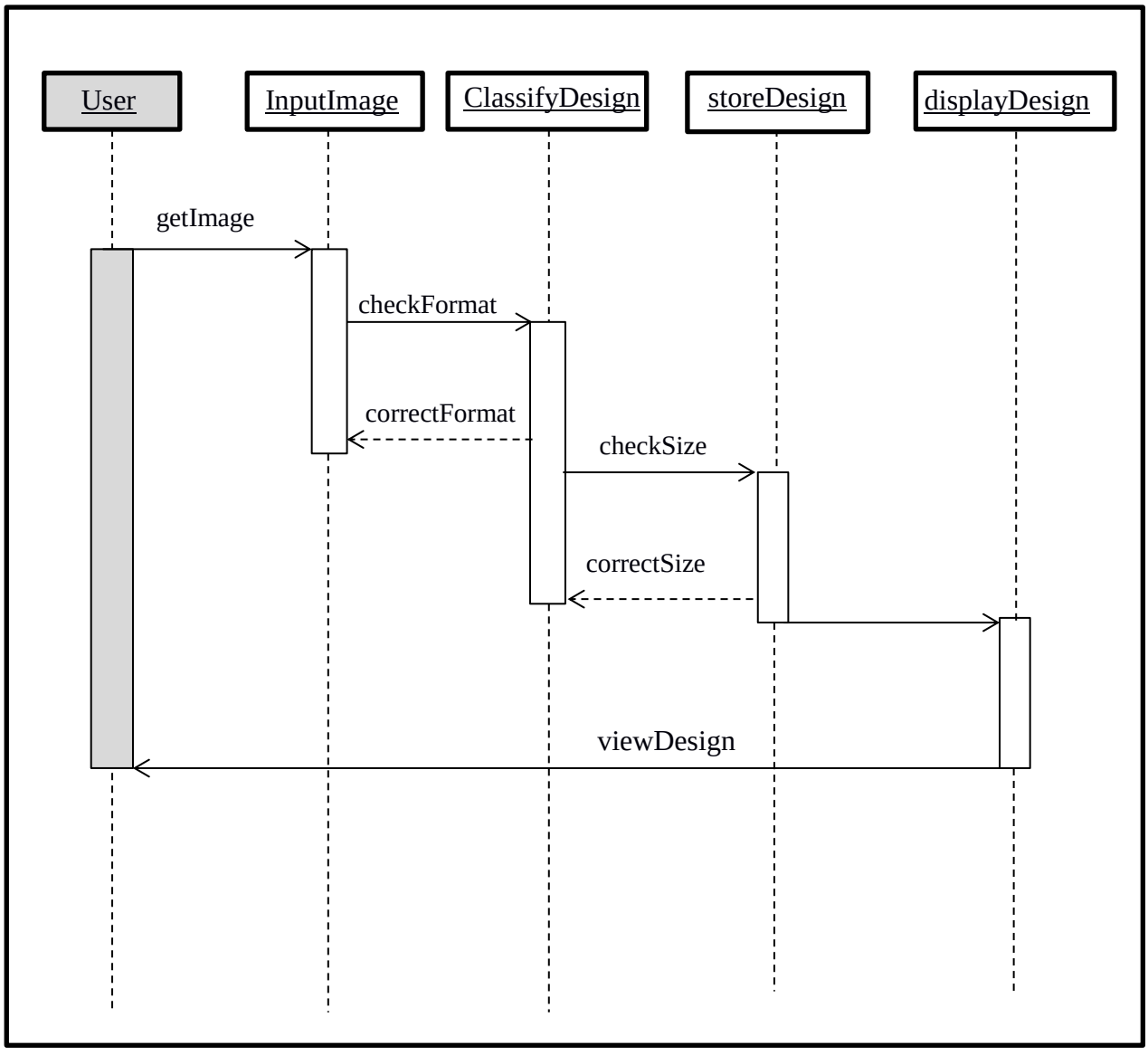


Figure 4.5: Sequence Diagram

4.7 Data Flow Diagram

Figure 4.6 illustrates the step by step processes followed in the application and the data stores of various data. A registered user logs into the system and his credentials verified. Each user has an accessible and editable user profile. After login the user is

presented with a main menu where they can select between public designs, private designs and the dashboard. Unregistered users identified as guests have limited access to view public designs only. All design product information is stored in a central database. The images are stored in an accessible location to the database.

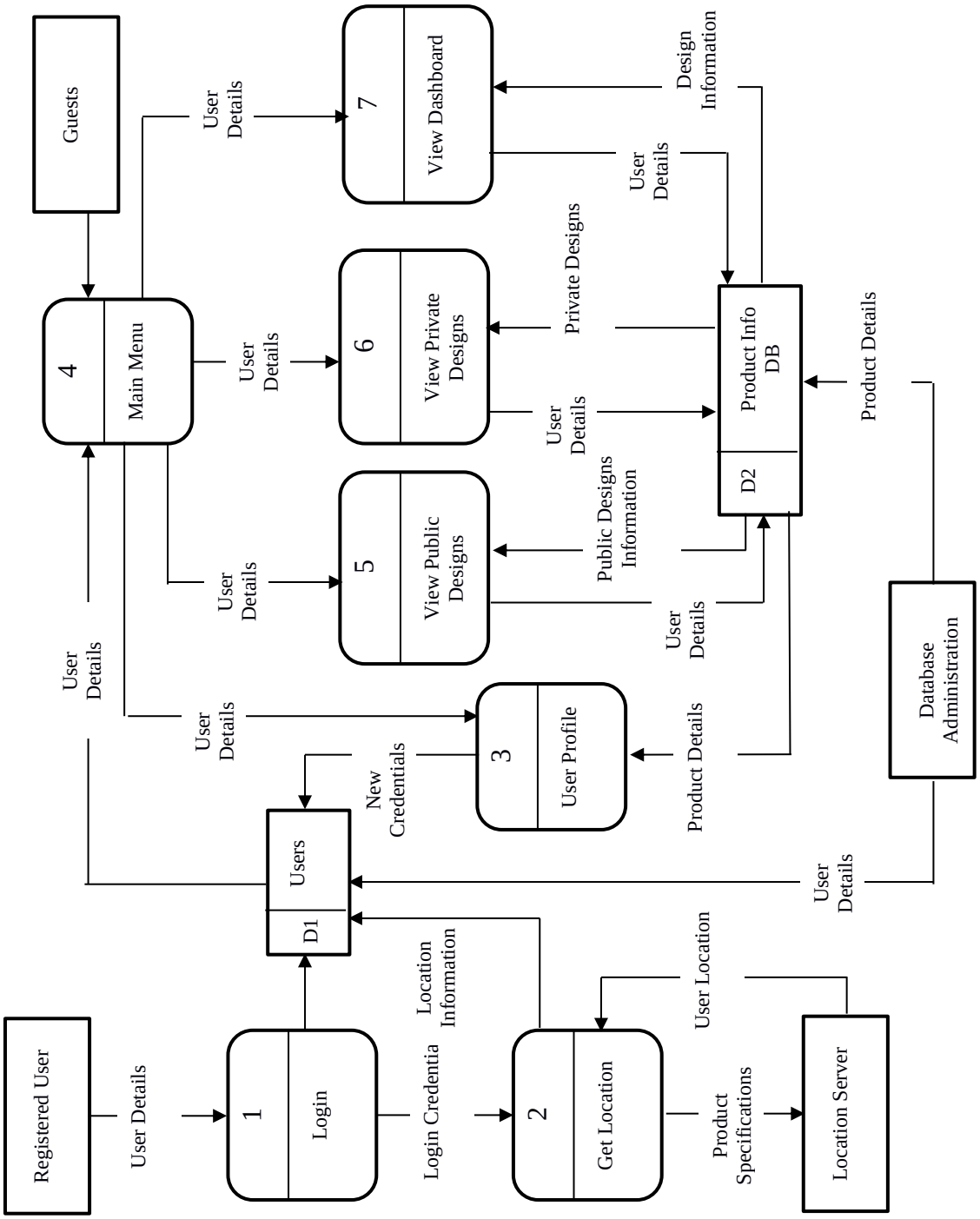


Figure 4.6: Data Flow Diagram

Chapter 5: System Implementation and Testing

5.1 Introduction

The research resulted into an application that can run as a web application on mobile devices where registered users have access to the main menu. It began with the input of a design either as a sketch on the device screen or an upload of a photo of an existing design either as a sketch or a proper image. The image was checked for proper format and size, and then categorized as per the users input into either a public or private design. Once the image is classified, it is visible to registered users and guests if it is in the public designs and only visible to the authorized user if it is in the private designs.

5.2 System Components

5.2.1 Login and registration

When a user launches the application, they find a login interface. This was created to enhance security and ensure only serious users interact with the system. Users are initially required to register, where they provide a name, username, password and email. During login, the system verifies usernames and password against those in the database. There are two levels of login, normal user and administrator. Unregistered users are allowed to only view the public designs but not participate.

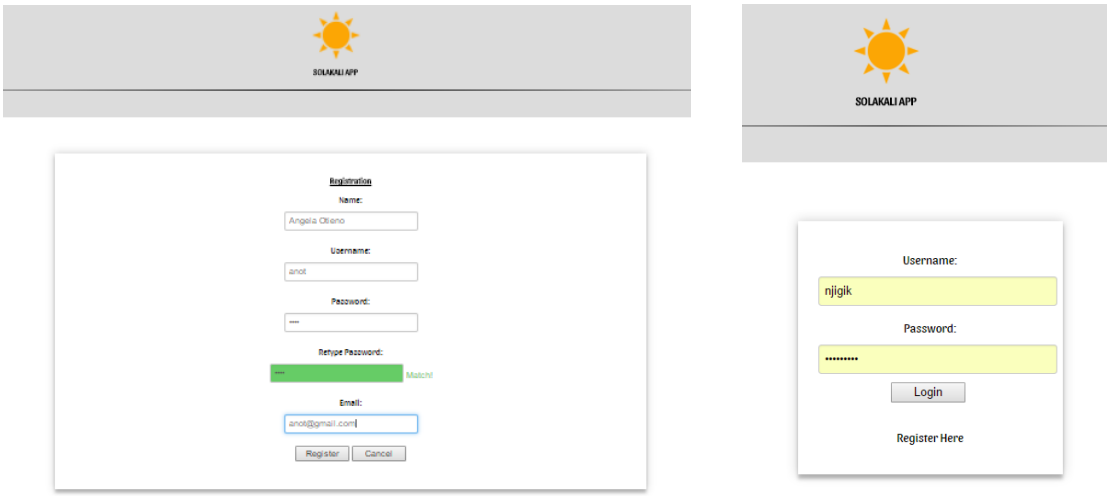


Figure 5.1: Solar Application Registration and Login

5.2.2 Main Menu

Once logged in, the user find the main menu which comprises of the home, private deigns, public designs and client dashboard. It also shows the name of the user who is currently logged in. The same interface also provides a form to create a new project where the user provides a project number, name and their phone number for contact. In the same page the user's own projects are displayed.

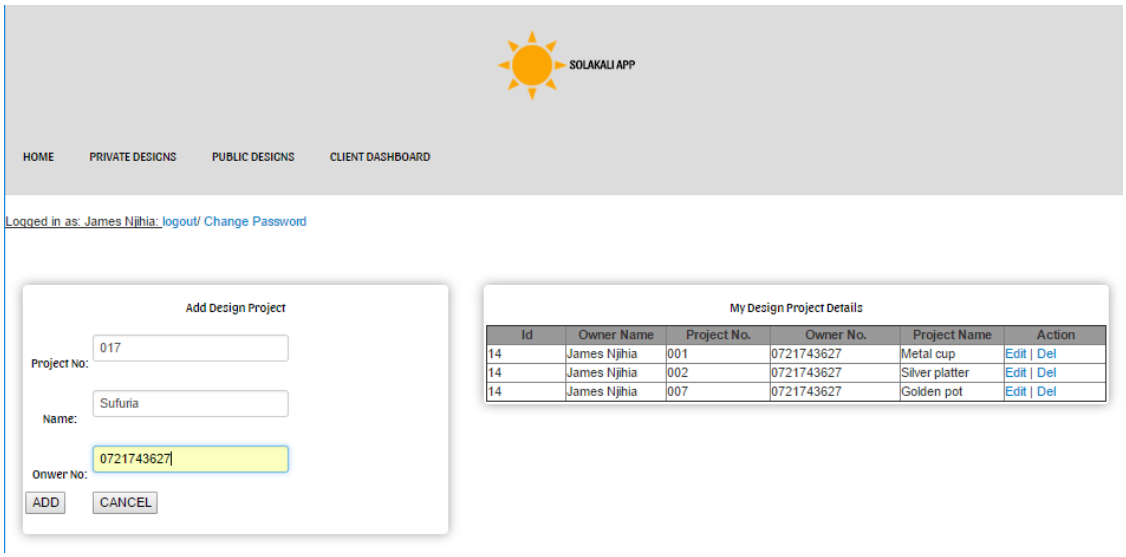


Figure 5.2: Main Menu and Design Project

5.3 System Implementation

5.3.1 Image/Sketch Input

A sketch is input by drawing on the screen with the finger, stylus or mouse. The user can choose from available shapes and colours to come up with a simple design.

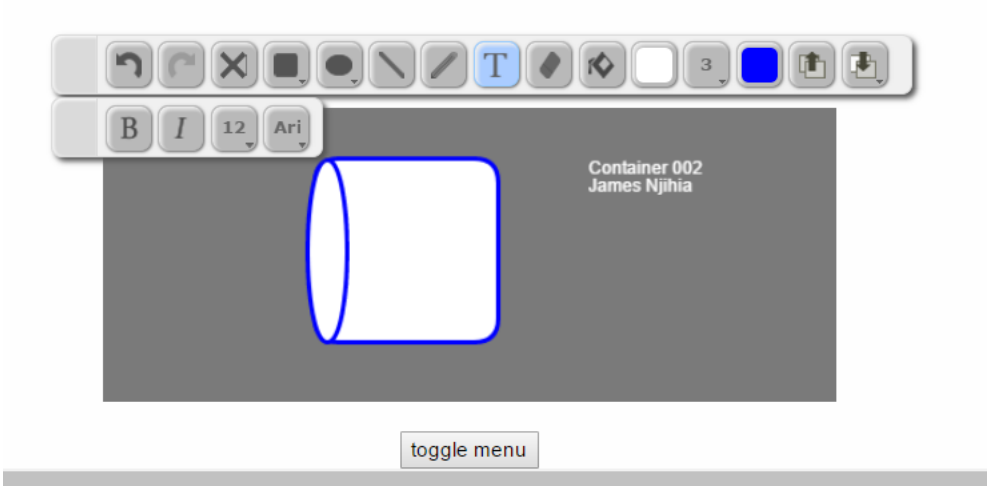


Figure 5.3: Sketchpad

Alternately an image can be uploaded which must be of the correct format and less than 5mb.

5.3.2 Image/Design Classification

The drawn sketch or uploaded image is put into one of the two available categories, public or private designs. The user can move a private design to the public gallery but not vice versa. The artisan can decide to patent his private designs as provided by the Industrial Property Act, Cap. 509. This can be done by submitting and filing an application with the KIPI's patent office and the patent renewed annually. The mobile application can protect the design as long as it is in private designs thus locked from public view. However, it does not provide a way to patent; the user has to initiate this process with the relevant authorities separately.

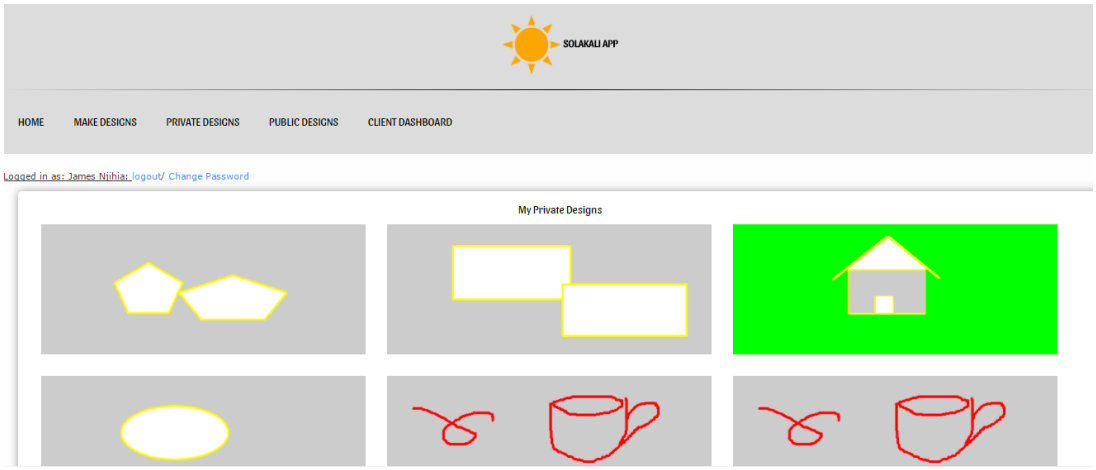


Figure 5.4: Images classified under private designs

5.4 Training and Testing the System

The developed system was first tested for efficiency in input. Several sketches were done using a finger on a touch screen tablet, then a stylus on the same touch screen and finally a mouse on a laptop. The researcher then attempted to upload images of different formats, within the size limit, including those not allowed which include .CR2, .BMP, and vector formats e.g. .SVG. Allowed formats include JPG, .JPEG, .PNG, .GIF and TIFF.

5.4.1 Usability Testing

The application was developed with ease of use in mind, particularly considering the usability knowledge and education levels of the target population. The User

Interface (UI) was thus tested by giving the prototype to four carpenters and observing the interaction with the device and the application and recording the feedback. Table 5.1 shows the results.

Table 5.1: Usability test results

Usability Test	**Description**	**Recorded Behavior**	**Errors**	**Remarks**
Ease of data entry	User Registration User Login	Easy registration and login.	Forgotten password from one respondent	Excellent with acceptable error
Navigation	Accessing main menu, and submenus	Easy navigation	None	Excellent as respondents familiar with menus
Image sketching	Sketching on screen using finger or stylus.	Fairly ease using stylus. Inaccuracy using finger	Accuracy issues while using finger.	Improvement on finger support.
Image upload	Uploading image from device storage.	Fairly easy from prior experience.	Stretching of photo	Need to work on aspect ratio.

5.4.2 Compatibility Test

The application was developed to run on any device supporting HTTP and web functionality being mainly developed from PHP and HTML and an SQL database. The application was tested on the following devices.

Table 5.2: Device compatibly test results

Device	Details	Platform	Screen Interaction Device	Compatible
Laptop	HP 250 G4 Notebook PC	Windows 10 Home 64bit	Mouse	Yes
Tablet	Samsung Galaxy Note 10.1 3G 2014 Edition	Android Lollipop 5.1.1	Stylus pen / Finger	Yes
Phone	Samsung Duos GT-S7262	Android Jelly Bean 4.1.2	Finger	Yes

5.5 Test Conclusions

The results from the tests carried out showed that the application works well with variations to each device and room for improvement. On the laptop which did not have a touch screen, the input device was a mouse which proved quite easy to use. Stylus was used on the tablet and proved easier to use than a finger on the touchscreen. The users described it as practical and easy to use, with the only fear being cost of devices with stylus. The application's response on different browsers was almost identically. This was tested on Chrome, Opera, Mozilla and Internet Explorer.

5.6 Software Flow

The application was made using PHP and HTML with a. To mimic a live site, the application was run on XAMPP from the localhost with Apache as the HTTP web server and MySQL as the database. Upon registration, the data was sent and stored into the database. During login this data was fetched for authentication. Once logged in, the application allows for the user to sketch or upload an image. A sketchpad with multiple colors and shapes to choose from is provided.

Once a sketch was made or an image was uploaded, a button requesting to save and to which category was pressed and the image stored in the device's storage. Related reference information for specific designs was stored in the database. The sketch could be recalled for individual or collaborative continuation of work.

Chapter 6: Discussions of Results

6.1 Introduction

The *Solakali* application uses sketches and uploaded images as input. Sketches are made on a device's surface using a mouse, stylus or a finger while images are uploaded from a storage space. Accuracy of sketches was tested on the basis of the desired product by the artisan versus the output. The artisans who tested the application described it as user-friendly, especially with a stylus, though most described use of a finger to draw as being less accurate as opposed to using the traditional pen on paper. However, most described storage of designs on paper and printed photos as being stressful as they wear out, get damaged or lost over time.

The researcher aimed to focus the mobile application on *jua kali* products since this seemed a neglected area, as successful mobile applications had already been created, *Afya Poa,* for micro health insurance and *Mbao pension scheme,* for voluntary retirement savings scheme. Consequently, there's a gap left and a need to shift focus from the artisans to the products through an appropriate mobile application than enables collaborative creation and sharing of product designs.

6.2 Design Oriented Cluster

From the research findings depicted in Appendix C, Table C.5, 90% of the respondents indicated they have original designs with only 6% responding that the nature of their business did not involve any designing. This indicates the area has artisans that engage a lot in coming up with new ideas while improving on others. Zeng (2008) states that in most clusters studied, the businesses were started by traders, traditional craftsman, artisans and others who had inherited their knowledge and skills from family and kinship ties or local apprenticeships.

Zeng (2008) further cites that most of them started with small and simple operations, then gradually expanded and upgraded. For example, in the cases of the Kamukunji metalwork cluster in Kenya and the Nnewi auto parts and Otigba computer clusters in Nigeria, most businesses started by trading or repairing, and then gradually evolved into assembling and manufacturing activities This gave the researcher the idea of incorporating into the application ability to incrementally edit an existing sketch and save it as a separate design so the incremental progress can be tracked.

6.3 Knowledge and Technology Gap

The Kamukunji cluster has a combination of indigenous artisan skills and technological processes. These skills and processes, the researcher concluded, can be captured and stored in the application to avoid loss while attributing each gradual incremental skill change in a design to an artisan.

Zeng (2008) says that knowledge and technological spillover and transfer could be enhanced if the image and visibility of the cluster is improved. The application provides a more secure and permanent way to store this knowledge in form designs and specifications for future reference. It also provides an online platform where two or more artisans in different locations could share design ideas and turn them into permanent images real-time.

6.4 Smartphone Use and the Immediate Environment

While a majority of 72% of the respondents indicated they would use the application to manage and store their designs and sketches, 39.13% cited high cost of purchase as the reason for not owning smartphones while 17.4% cited maintenance issues as depicted in Appendix C, Table C.4. The researcher thus concluded that it was highly likely due to the harsh working conditions and lack of security in the cluster.

6.5 Validation of the Application

The proposed application was tested and validated for accuracy to determine its suitability for real-life day to day application. This was done using confusion matrix. 10 sketches were made by different artisans and others requested to identify the sketches made.

6.5.1 Validation for Sketches

From the 10 sketches made, 8 were identified correctly giving an accuracy of 80% and an absolute error of 2 as shown in Table 6.1.

Table 6.1: Classification output for sketches

Classes of Sketches	**Frequency**	**Percentage (%)**
Correctly identified sketches	8 (x_0)	80.00
Incorrect identified sketches	2	20.00
Total	**10 (x)**	**100.00**

Absolute Error $\Delta_x = x_0 - x = 8 - 10 = |-2| = 2$

Relative Error $\delta_x = (x_0 - x) / x = 2/10 = 0.2$

Table 6.2: Confusion Matrix for sketches

		Class Results	
		Identifiable sketches	**Unidentifiable sketches**
Actual Class Count	**Image uploads**	8	2

6.5.2 Validation for Images

Validation for images was done using 20 images of different formats with the aim of checking if the system could accept correct formats and bring an error for incorrect formats. Correctly and incorrectly uploaded images were classified under predicted while correctly and incorrectly rejected images were put under actual.

Table 6.3: Confusion Matrix for images

	n=20	**Predicted Class Results (Uploaded Images)**		
		Incorrectly	**Correctly**	
Actual Class Count (Rejected Images)	**Incorrectly**	TN=5	FP=3	8
	Correctly	FN=0	TP=12	12
		5	15	

i. **True Positives (TP)**: images with correct formats which were uploaded correctly. TP=12
ii. **True Negatives (TN)**: images with incorrect formats which were rejected. TN=5
iii. **False Positives (FP)/Type I Error**: images with incorrect formats which were uploaded. FP=3
iv. **False Negatives (FN)/ Type II Error**: Images with correct formats which were incorrectly uploaded. FN=0

A list of rates was generated from the confusion matrix

i. **Accuracy**: how often the application uploads correct image formats
(TP+TN)/Total = (12+5)/20 = 0.85
ii. **Error/Misclassification Rate:** how often the application is wrong
(FP+FN)/Total = (3+0)/20 = 0.15
iii. **Recall/ True Positive Rate:** How often the system is accurate
TP/Actual Correctly = 12/12=1
iv. **Specificity:** How often it predicts wrong images as wrong
TN / Actual Incorrectly =5/8=0.625
v. **Precision:** How often it predicts correct images as correct
TP / Predicted Correctly =12/15 =0.8
vi. **Prevalence:** Actual Correctly /Total = 12/20 =0.6
How often the correctly condition occurs in the samples.

Chapter 7: Conclusions and Recommendations

7.1 Conclusions

The primary data of this research was collected from Jua kali artisans from various disciplines who acknowledged that although there have been significant improvements in the collaboration of design through social media, there was still no unique platform tailored to their kind of work. They had to adapt to using WhatsApp, Facebook and other means on social media to collaborate and market their work. The application was created to adapt to their work and specific needs.

The research focused on the *jua kali* artisans being able to take part in the technological revolution by using their mobile devices not only for basic communication but also for collaboration and sharing their technological know-how. The research was based on artisans being able to sketch or draw on their device screens and sharing the ideas with each other. They can also choose to upload images that are later classified into distinctive classes to allow easy searching and collaboration.

By an artisan being able to own a design and have it recognized by his name on the platform enables him to reach a niche market, or share a unique skill that could have been otherwise not well exposed. The aspect of collaboration surpasses geographical barriers thus artisans in two different locations can still be able to work together using the system.

7.2 Shortfalls of the Research

The application and the research fell short of some perceived expectations by the researcher.

i. The research covered only one geographical area with a representative sample of 50 respondents which might have introduced unintended bias.
ii. The research was limited to *jua kali* artisans
iii. The application did not incorporate all possible features that can process images, including 3D and animation functionalities.
iv. The knowledge level of the artisans in using smartphones and stylus pens was not put into consideration. It was assumed they would acquire it through use.

7.3 Contribution of System to Research

Based on the findings of the difficulty of using the manual systems, the application offers a design and storage facility than paperwork and disorganized digital images randomly stored in cameras and phones. The application forms a basis for more research and improvement on digitization and cataloguing of *jua kali* products. It also explores the option of creating a versatile online market for *jua kali* products where artisans can receive designs and sell directly to clients.

7.4 Recommendations and Suggestions for Future Research

These are recommendations based on the findings of this research.

i. The application can be expanded to include an online market where clients can purchase ready goods in real-time and have them delivered.
ii. The architecture of the application can be improved to allow more detailed sketching and 3D modelling.
iii. Geographical locations can mapped into the applications from the existing *jua kali* clusters so one can identify from which cluster a collaborator is from.
iv. The application can be enhanced to run on various vendor platforms and devices including android, iOS and Windows with cloud support to allow offsite backups.

References

Bhatnagar, M. & Singh, K. P. (2013). Research Methodology as SDLC Process in Image Processing: International Journal of Computer Applications. 77 (2)

Bull, C., Daniel, S., Kinyanjui, M.N. & Hazeltine, B. (2014). Country Study on Innovation, Intellectual Property and the Informal Economy: The Informal Metalworking Sector in Kenya. *Committee on Development and Intellectual Property (CDIP*/13/INF/3*),* Geneva, Annex pp. 2.

Dennis, A., Roth, R. M., & Wixom, H. B. (2012). Systems Analysis and Design. 5th Edition. John Wiley & Sons, Inc.

Economou, D. & Gavalas, D. (2011). Development Platforms for Mobile Applications: Status and Trends. *IEEE Software 28,* 77-86. doi: 10.1109/MS .2010.155

Fatharani, S. L., Kusumo, D. S., & Suwawi, D. D. (2016). Software Architecture Design of Collaborative Learning System for Undergraduate Thesis Guidance Application Using Aspect Oriented Architecture Description Language (AO-ADL). *Fourth International Conference on Information and Communication Technologies (ICoICT).* Bandung: IEEE.

Finances Online. (2016). *Types of Collaboration Software: 5 Groups You Should Know About.* Retrieved from collaboration-software.financesonline.com: https://collaboration-software.financesonline.com/types-of-collaboration-software-5-groups-you-should-know-about/

House, C. H., & Price, R. L. (1991). The Retun Map: Tracking Product Teams. *Harvard Business Review*, 50.

Isenberg, P., Elmqvist, N., Scholtz, J., Cernea, D., & Ma, K.-L. (2011, October). Collaborative Visualization: Deinition, Challenges, and Research Agenda. *Information Visualization, 10*(4), 311-315.

Jabar, M. A., Sidi, F., Ghani, A. A., & Ibrahim, H. (2009). An Investigation into Methods and Concepts of Qualitative Research in Information System Research. *Computer and Information Science, 2*(4). doi:10.5539/cis.v2n4p47

Johnson, S.C. & Thakur D. (2015). Mobile Phone Ecosystems and the Informal Sector in Developing Countries – Cases from Jamaica. *The Electronic Journal of Information Systems in Developing Countries,* 66(6), 1-22.

Jua Kali Intermediate Technology. (2016, November). *Introduction: Jua Kali Information*. Retrieved from http://juakali.info

JuaKali Workforce Limited. (2015, November). *about: JuaKali*. Retrieved from http://juakali.co.ke

Jumia. (n.d). In Wikipedia. Retriveded April 20, 2017, from https://en.wikipedia.org/wiki/Jumia

Kendall, K. E., & Kendall, J. E. (2011). *Systems Analysis and Design* (8 ed.). New Jersey 07458, One Lake Street, Upper Saddle River: Prentice Hall.

Kinyanjui, N. M. (2006, April). *Knowledge, Technology and Growth: The Case Study of Kamukunji Jua Kali Enterprise Cluster in Kenya*. Retrieved April 24, 2017, from uonbi.ac.ke: http://erepository.uonbi.ac.ke/handle/11295/3936

Komollo, F. O. (2010). Regularization of the Informal '*Jua kali*' Activities in Nairobi for Sustainable Development. *46th ISOCARP Congress*, 3.

Kothari, C. R. (2004). Research methodology: *Methods and Techniques*. New Age International.

Lanubile, F., Ebert, C., Prikladnicki, R., & Vizcaíno, A. (2010, March/April). Collaboration Tools for Global Software Engineering. (C. Ebert, Ed.) *software technology*, *0740*(7459), 54. Retrieved from http://ieeexplore.ieee.org/document/5420797

Orwa, B. (2007, January 25). Jua Kali Associations in Kenya:A Force for Development an form. *Reform Case Study*, pp. 1,2.

Patenting in Kenya. (2012, November). Retrieved from http://ihub.co.ke/

Salvador-Herranz, G., Bañó, M., Contero, M., & Camba, J. (2014). A Collaborative Design Graphical Tool Based on Interactive Spaces and Natural Interfaces: A Case Study on an International Design Project. *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design*, (p. 510).

Zab, S. (2015, May). The Growth of the Smartphone Market in Kenya. Nairobi. Retrieved April 25, 2017, from jumia.co.ke: https://www.jumia.co.ke/blog/whitepaper-the-growth-of-the-smartphone-market-in-kenya/

Zeng, D. Z. (worldbank.org, February 2008). Knowledge, Technology, and Cluster-based Growth in Africa. doi:http://dx.doi.org/10.1596/978-0-8213-7306-4

Appendix A: Originality Report

Mobile Application Framework for Collaborative Creation and Sharing of Jua Kali Product Designs: A Case Study of Kamukunji Enterprise Jua Kali Cluster

ORIGINALITY REPORT

25%	19%	9%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	siteresources.worldbank.org Internet Source	4%
2	Salvador-Herranz, Gustavo, Manuel Bano, Manuel Contero, and Jorge Camba. "A collaborative design graphical tool based on Interactive Spaces and Natural Interfaces: A case study on an international design project", Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD), 2014. Publication	3%
3	symbiosis.rmc.ca Internet Source	2%
4	Submitted to Strathmore University Student Paper	2%
5	www.jaqm.ro Internet Source	2%
6	Loksa, Dastyni, Nicolas Mangano, Thomas D.	2%

Appendix B: Research Interview Guide

NB: All information collected from respondents shall be treated with confidence and as such, will not be used in any way to their disadvantage. All respondents will anonymous in the course of this research.

SECTION A: For *Jua Kali* Artisans

1. What's your current *jua kali* occupation:
2. Do you have a smartphone?
   If not, why?
3. Do you have original or improved sketches and designs for your finished products?
   If yes, how do you store them?
4. Would you use a mobile application to manage and store sketches and designs of your finished products?
   If not, why?
5. Have you ever had collaborations in making designs for products with other artisans?
   If not, why?
6. Would you use a mobile application to collaborate with other artisans in making designs for products with other artisans?
   If not, why?

Appendix C: Interview Feedback

A total number of 50 random oral interviews were conducted using the interview guide in Appendix B. The responses were analyzed and presented as follows.

C.1 Gender of Respondents

Table C.1: Gender distribution of respondents

Gender	**Frequency**	**Percentage (%)**
Male	48	96.00
Female	2	4.00
Total	**50**	**100.00**

The resulting distribution showed a dominant number of males 48 (96%) in the *jua kali* cluster as compared to females 2 (4%). This implied that the *jua kali* cluster is a male dominated area and thus the functionality and interface of the application was created to appeal more to men.

C.2 Occupation

The study sought to find out the number of the different occupations represented in the Kamukunji *jua kali* cluster.

Table C.2: Occupation distribution of respondents

Occupation	**Frequency**	**Percentage (%)**
Carpenter	6	12
Blacksmith	5	10
Chicken house maker	1	2
Construction hardware	1	2
drum recycling dealer	1	2
dustbins maker	1	2
Firewood seller	1	2
Grill maker	2	4

hardware dealer	1	2
Iron sheets maker/seller	1	2
Jiko maker/seller	1	2
Kitchenware maker	1	2
Metal cutter	1	2
Metal box maker	1	2
motorcycle dealer	1	2
Scrap metal dealer	1	2
Smelter	1	2
Welder	22	44
Wheelbarrow maker	1	2
Total	**50**	**100**

Welders made the highest percentage at 22 (44%), then carpenters 6(12%) and blacksmiths. This is a clear indication that the application was best created to fit the welders' needs first, those being the majority, with functionality added to cater for the other groups in order of the frequency.

C.3 Ownership of a Smartphone

Table C.3: Respondents who own a smartphone

Own a Smartphone	**Frequency**	**Percentage (%)**
Yes	24	48.00
No	23	46.00
Occasionally	1	2.00
Non-disclosure	1	2.00
Total	**50**	**100.00**

Almost half of the respondents 24 (48%) said they own a smartphone with one indicating he has it occasionally, and on choosing not disclose. This could mean that the application could only be used by less than half the target population.

Table C.4: Respondents on why not own a smartphone

Why not own a Smartphone	Frequency	Percentage (%)
Complexity in use	7	30.43
High cost	9	39.13
Maintenance	4	17.40
No specific reason	3	13.04
Total	**23**	**100.00**

Of the 23 respondents who said they do not own a smartphone, 7(30.43) cited complexity of use as the reason, 9 (39.13%) cited high cost of purchase, 4 (17.4%) cited maintenance issues and 3 (13.04%) not have any specific reason. This may indicate a lack of interest; fear or sheer ignorance of new technologies thus need for detailed user training and clear guides and help menu while creating the application and maybe need to de-stigmatize the smartphone among the *jua kali* sector.

C.4 Have Original or Improved Designs

Table C.5: Respondents who have original or improved designs

Have original or improved designs	Frequency	Percentage (%)
Original	45	90.00
Improved	2	4.00
Not applicable	3	6.00
Total	**50**	**100.00**

Majority of the respondents 45 (90%) indicated they have original designs, while 2 (4%) stated they have improved designs. 3 (6%) responded that the nature of their business did not involve any designing. Although the researcher clearly articulated to the respondents the difference between original and improved designs, there may be a degree of ambiguities in the high response rate of 90% having original designs as most of the products in display did not appear to be original but modified or improved. Nevertheless, the high response rate may indicate a multiple claim of

ownership of some designs. Thus this informed the researcher of a need to create and track ownership in the application so as to track a design to its original source and attribute specific improvements to the specific contributors in collaboration.

C.5 Storage of Original Designs

Table C.6: Storage of original or improved designs

How do you store the original designs	Frequency	Percentage (%)
Memory	26	55.32
Photos	5	10.64
Not disclose	9	19.15
No response	7	14.89
Total	**47**	**100.00**

Of the 47 respondents who indicated they had original or improved designs, 26 (55.32%) indicated they store them in memory, 5 (10.64%) who were all carpenters, indicated they have photo albums, 9 (19.15%) chose not to disclose while 7 (14.89%) were not responsive. This may indicate that only carpenters (10.64%) seem to have manual records of their finished product designs in the form of photos. None of the respondents had stored sketches. Majority of the 55.32% indicated that they did not need any physical or storage as they had repeated the designs for years.

C.6 Use of Application to Manage and Store Designs and Sketches

Table C.7: Respondents who would use the application to manage and store designs and sketches

Do you use the application to manage / store designs and sketches	Frequency	Percentage (%)
Yes	36	72.00
No	14	28.00
Total	**50**	**100.00**

Majority 36 (72%) of the respondents indicated they would use the application to manage and store their designs and sketches. Out of the 36 % who responded yes, 15 were asked why and they responded as follows.

Table C.8: Respondents on why they would use the application to manage and store designs and sketches

Why use application to manage / store designs and sketches	**Frequency**	**Percentage (%)**
More customers	5	33.33
Business Growth/ Opportunities	2	13.33
Improve products	1	6.67
Storage management	2	13.33
Yes, but currently satisfied	3	20.00
Used similar App before	1	6.67
Wrong business	1	6.67
Total	**15**	**100.00**

The results may indicate the application is a viable tool for more than just storage and management but also as a virtual market for exposing products to existing and potential clientele. Out of the 14 (28%) who responded no, 1 indicated a previous OLX con incident, 2 used similar applications that failed and 2 were satisfied with their businesses as they were.

C.7 Use of Application for Creative Collaboration with other Artisans

Table C.9: Respondents on if they would use the application for creative collaboration with other Artisans

Would you use the application for creative collaboration	**Frequency**	**Percentage (%)**
Yes	18	36.00
No	29	64.00
Total	**50**	**100.00**

Table C.10: Respondents on why they would not use application to collaborate

Why would you not use the application to collaborate	**Frequency**	**Percentage (%)**
Lack of trust / Exposure risk	10	76.92
Prefer old-Fashioned ways	2	15.39
Complexity	1	7.69
Total	**13**	**100.00**

A majority of the respondents 29 (64%) would not use the application for collaboration. Out of these 13 were asked why they would not and 10 (76.92%) cited lack of trust and risk of exposure, 2 (15.39%) preferred remaining old-fashioned and 1 (7.69%) found the concept complex. This enlightens the researcher on the need to include security features like authentication, data encryption and backup to eliminate lack of trust or risk to exposure while making the application as user friendly as possible from interface to functionality.

Out of 18 who responded yes, 9 (50%) said they would use the application for creative collaboration if they had an opportunity. This enlightens the researcher to create more record and management features in the application for the majority and less collaboration features as value addition-features for the minority.

Appendix D: Use Case Tables

Table D.1: Edit Public Designs use case

Use Case:	**Edit Public Designs**
Primary Actor	User
Pre-condition	Registered Artisan/Client with internet enabled device
Post condition	Edit Public designs

Actor	**System**
1. User logs in	
	2. System displays Client Dashboard
3. User chooses Public Designs	

Table D.2: Edit Private Designs use case

Use Case:	**Edit Private Designs**
Primary Actor	User
Pre-condition	Registered Artisan / Client
Post condition	Edit Private Designs

Actor	**System**
1. User logs in	
	2. System displays Client Dashboard
3. User chooses Private Designs	

Table D.3: Manage Users use case

Use Case:	**Manage Users**
Primary Actor	Administrator
Pre-condition	Artisan / Client registered at elevated level
Post condition	Add/ Delete Users

Actor	**System**
1. User logs in at elevated level	
	2. System displays list of current users
3. Administrator edits or deletes users	

Table D.4: Manage Designs use case

Use Case:	**Manage Designs**
Primary Actor	Administrator
Pre-condition	Artisan / Client registered at elevated level
Post condition	Add/ Delete Designs

Actor	**System**
1. User logs in at elevated level	
	2. System displays private and public designs
3. Administrator adds/deletes designs	

Table D.5: Manage Social Media use case

Use Case:	**Manage Social Media**
Primary Actor	Administrator
Pre-condition	Artisan / Client registered at elevated level
Post condition	Add/ Edit/Delete users, designs and comments

Actor	**System**
1. Administrator logs in to respective social media platform at elevated level	
	2. System displays users comments and pictures
3. Administrator goes through user comments and uploads	
4. Administrator edits/ deletes user comments and uploads.	

Appendix E: Sample PHP / jQuery Code

E.1 Image Creation/ Upload Sample Code

```
<?php

$image = imagecreatefrompng($_POST['image']);
$id = uniqid();

imagealphablending($image, false);
imagesavealpha($image, true);
imagepng($image, 'uploads/wPaint-' . $id . '.png');

// return image path
echo '{"img": "../test/uploads/wPaint-' . $id . '.png"}';
```

E.2 w.Paint.jquery.json Sample Code

```
{
  "name": "wPaint",
  "title": "wPaint jQuery Paint Plugin",
  "description": "A jQuery paint plugin for a simple drawing surface that you can easily pop
into your pages, similar to the basic windows paint program.",
  "keywords": [    "websanova",
                   "wPaint",
                   "paint",
                   "canvas",
                   "html5"  ],
  "version": "2.5.0",
  "author": {
    "name": "Websanova",
    "email": "rob@websanova.com",
    "url": "http://websanova.com"
  },
  "maintainers": [    {
      "name": "Websanova",
      "email": "rob@websanova.com",
      "url": "http://websanova.com"    }  ],
  "licenses": [
    {
      "type": "MIT",
      "url": "https://github.com/websanova/wPaint#license"
    }
  ],
  "bugs": "https://github.com/websanova/wPaint/issues",
  "homepage": "http://wpaint.websanova.com",
  "docs": "https://github.com/websanova/wPaint#wpaintjs",
  "download": "https://github.com/websanova/wPaint/tags",
  "dependencies": {
    "jquery": ">=1.5"
  }
}
```

Appendix F: Sample SQL Code

```
--
-- Table structure for table `tbl_public`
--

CREATE TABLE `tbl_public` (
  `id` int(11) NOT NULL,
  `createdby` varchar(300) NOT NULL,
  `jobname` varchar(300) NOT NULL,
  `jobpic` varchar(300) NOT NULL,
  `createdby_id` int(11) NOT NULL,
  `isActive` tinyint(1) NOT NULL DEFAULT '1'
) ENGINE=InnoDB DEFAULT CHARSET=latin1;

--
-- Dumping data for table `tbl_public`
--

INSERT INTO `tbl_public` (`id`, `createdby`, `jobname`,
`jobpic`, `createdby_id`, `isActive`) VALUES
(1, 'Mwangi', 'Magic Box', '699611.png', 13, 0),
(2, 'Mwangi', 'Cup', '60327.jpg', 13, 0),
(3, 'James Njihia', 'ceramic_jiko', '486567.jpg', 13, 0),
(4, 'James Njihia', 'Jiko', '694002.png', 13, 0),
(5, 'James Njihia', 'Yellow pan', '872321.png', 13, 0),
(6, 'James Njihia', 'jiko3', '966526.jpg', 13, 1),
(7, 'James Njihia', 'Pan', '630954.png', 13, 1);

-- --------------------------------------------------------

--
-- Table structure for table `tbl_uploads`
--

CREATE TABLE `tbl_uploads` (
  `id` int(11) NOT NULL,
  `createdby` varchar(100) NOT NULL,
  `jobname` varchar(100) NOT NULL,
  `jobpic` varchar(100) NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1;

--
-- Dumping data for table `tbl_uploads`
--

INSERT INTO `tbl_uploads` (`id`, `createdby`, `jobname`,
`jobpic`) VALUES
(20, 'James Njihia', 'jiko6', '966526.jpg'),
(23, 'James Njihia', 'water_can', '692935.jpg'),
(24, 'James Njihia', 'Container', '650283.png'),
(25, 'Shiru', 'jiko', '577785.jpg');

-- --------------------------------------------------------
```