

**A MACHINE LEARNING APPROACH TO ENHANCE IMPORT ITEMS VALUATION**

**ACCURACY IN UGANDA’S CUSTOMS FRAMEWORK**

**BY**

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# ABSTRACT

Accurate import valuation in Uganda's customs framework is important for revenue growth and economic development of the importing country and for promoting fair trade practices amongst countries. Traditional methods of valuation have been inconsistent, which has led to a significant loss of revenue and disputes. The complexity of this issue, coupled with the rapid growth of international trade, underscores the need for technological solutions. This thesis seeks to address the problem at hand by inventing machine learning approaches to solve the problem of inconsistent and inaccurate valuation of imports, thereby addressing systemic inefficiencies and laying the foundation for further studies in customs operations.

By leveraging Uganda’s historical trade data and advanced machine learning models, the research seeks to develop a precise valuation method. The scope of the research includes analyzing Uganda’s trade data from 2005 to 2023 to identify patterns and discrepancies. While the research focused on Uganda’s customs framework, it serves as a foundation for further research especially in similar developing countries.

To address the problem at hand, we employed a quantitative research method while harnessing the power of artificial intelligence. Data was mainly collected from primary sources like customs agencies, Uganda trade datasets available publicly, and those retrieved from internet sources and secondary sources along with WTO and WCO databases. We applied the linear regression model, random forests model, XGBoost, and neural networks. Key variables like unit price, country of origin, and market value rate were analyzed to output excellent results.

The machine learning methods registered an outstanding performance in predicting accurate import values in comparison to standard existing methods. The Random Forest model particularly, showed an excellent 95 % accuracy in predicting the accurate value of imports. The artificial neural network registered 89.28 % accuracy in valuation prediction, highlighting the effectiveness of those strategies.

The findings imply enormous benefits for Uganda's customs, which include enhanced revenue collection reduced valuation disputes, and overall compliance with trade regulations. The results demonstrate the power of machine learning in predicting the accurate value of imports and generally serving as a foundation for similar economies. Based on the study findings, the research offers several recommendations for policymakers, including well-planned change management and developing a pool of AI experts in Customs.

# DECLARATION

I, **PAUL SENTONGO** thus declare that this is my original work, it is not plagiarized, and it has not been submitted to any other institution for an award.

Name……………………………………….

Signature………………………………..

Date…………………………………………

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# LIST ACRONYMS AND ABBREVIATIONS

UNCTAD: The UN trade data from the United Nations Conference on Trade and Development

ML: Machine learning

Dual Attentive Tree Embeddings: (DATE) a machine learning model

BERT: Bidirectional Encoder Representations from Transformers

NLP: Natural Language Processing, a field of artificial intelligence. Helps computers to communicate with humans in their languages.

WCO: World Customs Organization: A global customs regulator

EAC - East African Community

GATT - General Agreement on Tariffs and Trade

URA - Uganda Revenue Authority

RECTS - Regional Electronic Cargo Tracking System

DRC - Democratic Republic of the Congo

GPS - Global Positioning System

HS - Harmonized System

HTS - Harmonized Tariff Schedule

SISAM - System Identification and Selection of Applied Methods

DATE - Dual Attentive Tree Embeddings

BERT - Bi-directional Encoder Representations from Transformers

ASYCUDA - Automated System for Customs Data

R2 - R-Squared

MAE - Mean Absolute Error

WCO - World Customs Organization

OECD - Organization for Economic Co-operation and Development

UNESCO - United Nations Educational, Scientific and Cultural Organization

IJLRHSS - International Journal of Law, Religion, and Human Social Studies

ARAS - Applied Research and Advanced Studies

# DEFINITION OF KEY TERMS

**Artificial Intelligence** can broadly be defined as a “set of statistical tools and algorithms that combine to form intelligent software enabling computers to simulate elements of human behavior such as learning, reasoning and classification”(Vijay Kanade, 2022). The key characteristic of AI that it is technology that simulates human cognitive behavior.

**Machine learning** is “a subset of AI and can be defined as a family of techniques that allow computers to learn directly from examples, data, and experience, finding rules or patterns that a human programmer did not explicitly specify”(Human-versus Artificial Intelligence, n.d.).

Unless specified otherwise, AI is used interchangeably in this paper to reference ML, although it is acknowledged that in practice this is not strictly correct in all circumstances. The next chapters summarize some of the key concepts relevant to AI, but these are included mainly to provide a simplistic explanation of AI. AI (and ML) is a complex (and developing) area of technology, and the following paragraphs should not be viewed as attempting to provide a comprehensive explanation of the technology.

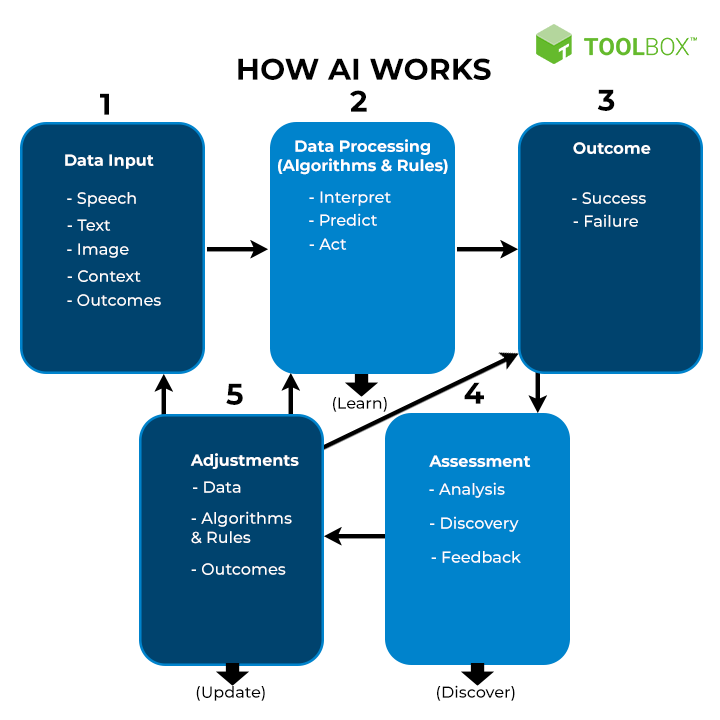
# CHAPTER ONE

## INTRODUCTION

“Artificial intelligence (AI) can be defined as an artificial creation of human-like intelligence that can learn, reason, plan, perceive or process natural language” (Vijay Kanade, 2022). “Artificial intelligence isn't one particular technology, but rather a large spectrum of computer structures and applications that have the capability to perform tasks associated with human intelligence”(Human-versus Artificial Intelligence, n.d.).

The AI wave has great economic potential worldwide. Indeed, some have already hailed AI as “the new oil”(*Data-Is-the-New-Oil-*, n.d.) since it has become a major resource that businesses rely on to streamline activities that enhance productivity.

This might not be a perfect analogy, but it does bring about the pleasure and high expectations surrounding the AI-driven economic system. “It is projected that the worldwide marketplace for AI solutions may be worth greater than GBP£30 billion through 2024, boosting productivity with 30 % in a few industries, and generating savings of up to 25%” as reported by (Koh, 2020) In every other estimate, “AI ought to contribute as much as USD$15.7 trillion to the worldwide economy in 2030, greater than the contemporary output of China and India. Of this, $6.6 trillion is probable to come back from elevated productivity and $9.1 trillion is possibly to come back from consumption-side effects” (Anantrasirichai & Bull, n.d.)

 Source: (Vijay Kanade, 2022)The process flow of AI:

The significance of this research lies in its contribution towards solving the persistent issues brought about by inconsistent and inaccurate valuation methods of imports within Uganda’s customs framework. In an era where global trade is a cornerstone of economic development, this research explores the application of machine learning mechanisms to streamline customs valuation in Uganda. By investigating the challenges that are associated with the existing valuation methods, this thesis seeks to streamline customs operations, increase revenue generation, tackle customs fraud, and to reduce customs valuation disputes. “The use of machine learning processes demonstrates not just the transformational capacity of artificial intelligence in customs administration, but also its broader impact on policy creation, regulatory compliance, and the promotion of fair-trade principles”. (AI Policies and Initiatives, 2019)

The research questions that will guide this project are intended to investigate the feasibility of machine learning methods in estimating the accurate value of imported commodities within Uganda's customs framework. Specifically, the research aims to find out which machine learning mechanisms in particular are able to handle the task and output world class results, investigate the factors that influence accurate valuation of imports in Uganda’s customs framework and to find out whether historical trade data can be processed to predict the accurate value of imports.

## 1.0.1 JUSTIFICATION OF THE STUDY

“Artificial intelligence has emerged as a revolutionary force with the potential to increase the growth of the global GDP. According to Forbes, the size of the artificial intelligence market is expected to reach $407 billion by 2027”(THE WORLD BANK GROUP, 2020) while addressing challenges such as limited resources and potential vulnerabilities, facilitating trading through AI-based tools creates a conducive trading environment through customer service and virtual assistants, thereby eliminating the need for manual human interventions.

In addition, (Delissen Supervisors et al., n.d.) clarify that AI-powered predictive analytics can help analyze past trade data, market valuations, and other external factors with better results. Thus, through artificial intelligence, customs authorities can accurately assess trade turnover, identify potential weaknesses in the system, optimize revenue collection and resource allocation.

## 1.0.2 SIGNIFICANCE OF THE STUDY

The complexities of international trade, combined with inadequate valuation methods, frequently lead to significant discrepancies in the declared import values. Uganda, like many developing nations, relies heavily on customs duties as a significant source of government revenue. According to a report by (Mikuriya & Cantens, n.d.), “developing countries collect between 30-70% of their tax revenue from customs duties”. However, the traditional methods of customs valuation have fallen short in addressing issues such as undervaluation, Mis-invoicing, and inconsistent application of valuation rules. These challenges have led to substantial revenue losses that hinders trade facilitation efforts.

The notion of customs valuation is based on the principles described in the World Trade Organization's (WTO) Agreement on Customs Valuation, which seeks to provide a fair, standard, and neutral system for valuing commodities for customs purposes. This system seeks to ensure that the value of goods declared at customs reflects their true market value, thereby preventing fraud and revenue loss. However, implementing these principles effectively in developing countries has been challenging due to limited technological capabilities and the complexity of international trade transactions(The Agreement on Customs Valuation, n.d.).

In context of Uganda, accurate valuation of imports remains critical for revenue collection and trade facilitation. The customs framework is faced with significant challenges that are often related to systematic undervaluation of imports, complex trade mis-invoicing schemes, and inconsistent valuation decisions across customs points. These issues are exacerbated by limited capacity for real-time products value information and the over-reliance on manual and subjective valuation methods(Tieu et al., 2023).

Recent reports indicate that Uganda lost approximately $4.9 billion due to import undervaluation and $1.7 billion due to export overvaluation between 2006 and 2015 (Monitor, 2023). This highlights the urgent need for innovative solutions to enhance the accuracy and efficiency of customs valuation processes.

Historical notes that Uganda lost approximately USD 450 million annually between 2018 and 2023 due to valuation – related irregularities (URA Annual report, 2023). This stemmed from several factors that included under invoicing, transfer pricing and misclassification of imported goods. The world customs organization (WCO) further noted that Uganda struggled with implementing the “WTO customs valuation agreement of 1995” effectively, which led to significant revenue losses (WCO, 2021).

The magnitude of Uganda’s customs valuation challenges was further exacerbated by its “geographical location being a land locked country”. The East African Community (EAC, 2022) further revealed that Uganda’s location complicates transit arrangements which made valuation verification hard.

Recent technological advancements in artificial intelligence and machine learning present endless opportunities and possibilities to transform the customs practices. This research is therefore driven by the urgent need to address the Uganda’s customs valuation challenges through innovative technological solutions. The researcher’s extensive experience in customs administration and data science domains highlights the potential for applying machine learning techniques to this area.

The overarching purpose of this research is to shed light on the application of machine learning mechanisms to enhance accurate valuation of imports in Uganda while highlighting the exact machine learning algorithms to handle the task at hand and also to find out the factors that influence accurate valuation of imports which serves to revolutionize the Uganda’s customs framework activities and enhance revenue growth.

## 1.0.3 BACKGROUND TO THE STUDY

### 1.0.3.1 Historical Background

Accurate valuation of imported items has long been a critical aspect of international trade and a vital source of revenue when managed properly. To appreciate the importance of this research, it is essential to evaluate existing valuation methods employed within Uganda’s customs framework. Historically, customs authorities have relied on manual processes that often lead to inconsistencies and inefficiencies. As globalization has accelerated in recent years, the volume of trade transactions has increased dramatically, necessitating the development of more reliable and standardized valuation methodologies.

The WTO Valuation Agreement, officially known as the Agreement on Implementation of Article VII of the General Agreement on Tariffs and Trade (GATT) 1994(The Agreement on Customs Valuation, n.d.), replaced the GATT Valuation Code during the Uruguay Round discussions that founded the WTO in 1994. This Agreement establishes a Customs valuation system based principally on the transaction value of imported goods (the price actually paid or due when sold for export), subject to certain adjustments. When estimating Customs value based on transaction value is not feasible, alternative approaches must be used in the following hierarchical order:

* The transaction value of identical goods
* The transaction value of similar goods
* The deductive value method
* The computed value method
* The fallback method

#### These methods seek to establish a fair, standard system for valuing imported commodities that is consistent with market reality, while banning arbitrary or fraudulent Customs values.

#### 1.0.3.2 Contextual Background

Like many developing countries, Uganda faces challenges related to accurate import valuation—ranging from under- and over-invoicing to misclassification of items—and insufficient trade data availability. These issues often result in disputes within courts, distortions in trade statistics, and undermining revenue collection efforts. The Uganda Revenue Authority as reported by (Tieu et al., 2023) indicated plans for improvement through technology-based approaches aimed at enhancing efficiency and transparency within its operations.

Therefore, applying machine learning methods offers a promising solution that could bolster existing plans while addressing current challenges effectively.

1.0.3.3 Theoretical Background

The theoretical foundation of this research is anchored in artificial intelligence (AI), particularly its subset known as machine learning (ML). By adopting machine learning techniques, this study illustrates how AI can enhance accuracy and efficiency within customs processes while contributing valuable insights into its application across various sectors of public administration and policy formulation.

# 1.0.4 PROBLEM STATEMENT

Historically, customs valuation processes in Uganda have been slow and cumbersome due primarily to reliance on traditional rules. In contrast, adopting machine learning has revolutionized these processes by automating tasks such as document classification and risk assessment while significantly reducing processing times. Amid evolving trade policies, machine learning's capacity for data analysis allows it to predict potential disruptions—an invaluable asset for ensuring compliance with regulations while facilitating efficient e-commerce logistics.

However, standard customs declarations remain detailed with numerous fields requiring completion; thus, complicating matters further for Ugandan authorities who grapple with illicit financial flows (IFFs) largely stemming from inaccurate import valuations—resulting in an estimated 20% loss in potential revenue according to Joan Salmon's report published by Daily Monitor on November 29th, 2022. Salmon cites results from the United Nations High-Level Panel on Illicit Financial Flows from Africa (2015), which claimed that such outflows cost Africa more than $50 billion per year, a number that exceeds several countries' development levels.

Accordingly, Global Financial Integrity's report (2021) revealed that “Uganda lost approximately 18% of total trade from 2020-2021 due specifically to trade mis-invoicing”(Mugyenyi et al., 2023)—a trend persisting year-on-year given limited access to real-time market price information alongside difficulties verifying declared values compounded by inadequate technological infrastructure necessary for early detection regarding discrepancies tied directly back towards item valuations established through WTO guidelines yet remaining challenging.

This comprehensive overview sets forth a clear understanding of both contextually relevant issues surrounding custom valuations alongside theoretical frameworks underpinning proposed solutions via innovative methodologies like those offered through machine learning applications tailored specifically towards enhancing accuracy within Ugandan frameworks overall whilst driving forward economic growth prospects sustainably into future endeavors ahead.

## 1.4 RESEARCH QUESTIONS

* Can machine learning models accurately predict imported item prices in Uganda’s customs framework?
* Which machine learning algorithms execute the task of predicting accurate prices of imports?
* What are the factors affecting import valuation accuracy in Uganda’s customs operations, and how can machine learning models embrace these factors?
* Can historical import data be used to predict the accurate values of the imported items in the Uganda customs framework?

## 1.5 HYPOTHESIS

The main goal of the research was to find out whether machine learning techniques could handle accurate valuation of imports within Uganda’s customs framework.

The hypotheses were formulated based on the premise that the introduction of advanced technologies, particularly machine learning approaches, could significantly improve the accuracy of import valuations and streamline customs operations.

### 1.5.1 NULL HYPOTHESIS (HO)

There isn't any notable difference in the accuracy and efficiency of customs valuation processes in Uganda with the introduction of machine learning methods compared to traditional methods.

### 1.5.2 ALTERNATIVE HYPOTHESIS (H1)

The introduction of machine learning methods significantly improves the accuracy and efficiency of customs valuation processes in Uganda compared to traditional methods.

These hypotheses were tested using appropriate statistical strategies that determined the validity of the claims. The outcomes provided insights into whether the implementation of machine learning methods could enhance customs valuation accuracy and efficiency, thereby informing policy and practice in the field.

## 1.6 OBJECTIVES OF THE STUDY

### 1.6.1 Main Objective

To develop an accurate and transparent import valuation method using machine learning techniques to enhance revenue growth and economic development of Uganda.

### 1.6.2 Specific Objectives

1. To evaluate the existing literature on machine learning applications in the valuation of imported items.
2. To analyze and process historical import data to predict the accurate values of imported items in Uganda customs.
3. To develop and validate a machine learning model tailored to accurately value imports reducing errors and fraud.

## 1.7 THEORETICAL / CONCEPTUAL FRAMEWORK

This research was based on theories of international trade, economic regulation, and artificial intelligence. The theoretical framework combined concepts from the Heckscher-Ohlin model of international trade, which explains how countries benefit from trading goods in which they have a comparative advantage, and regulatory compliance theory, which focuses on how effective regulatory enforcement can improve compliance and reduce fraud.

In addition, the conceptual framework includes data science methods that emphasize the use of artificial intelligence and predictive analytics to process large volumes of data and identify discrepancies in values. The framework suggests that accurate and data-driven valuation models could significantly improve the customs valuation process by reducing under and over-valuation of imports, thereby improving revenue collection and trade policy effectiveness. While applying advanced technologies and following a strong theoretical foundation, the research aimed to develop practical solutions to customs valuation challenges that contribute to Uganda's economic growth and regulatory effectiveness.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

This chapter presents a review of the existing literature that is relevant to the research, especially in areas of customs valuation, the application of machine learning solutions, and their relevance to Uganda’s customs.

The related areas follow from the research objective, which is repeated here:

*“To develop an accurate and transparent imports valuation method using machine learning techniques to enhance revenue growth and economic development of Uganda.”*

The main emphasis is placed on the theoretical foundation of customs valuation, the main issues associated with existing valuation methods in Uganda and other related developing countries, and most importantly how machine learning can transform the customs and provide solutions that enhance the accuracy of import valuation. By incorporating insights from various studies, this chapter aims to establish a solid foundation for the research questions posed in this study.

### 2.0.1 Customs valuation concepts and principles

Customs valuation represents a critical component of international trade, serving as a basis for calculating duties and taxes levied on imported goods (WCO, 2022). The practice of valuation dates to the 1947 General Agreement on Tariffs and Trade (GATT), which established the first globally accepted principles of customs valuation (Wulf & Sokol, 2019).

As highlighted in chapter one of this thesis, the World Trade Organization’s agreement on customs valuation and actual cash value (ACV) later standardized these practices by providing six traditional methods for determining customs value in a hierarchical order (WTO, 2020). These include: The transaction value method, The transaction value of identical goods, The transaction value of similar goods, The deductive method, The computed method, and the Fall-back method. The Uganda Revenue Authority (URA) as the regulator, notes that the primary method of determining the customs value of imported goods is the transaction value method as per Article 1 of the agreement on customs valuation (GATT, 1994).

The World Trade Organization (WTO) further clarified that the basic principle is the transaction value, whereby the agreement stipulated that customs valuation shall, except in specified circumstances, be based on the actual price of the goods to be valued, which is generally shown on the invoice. This price, plus adjustments for certain elements listed in Article 8, equals the transaction value, which constitutes the first and most important method of valuation referred to in the Agreement.

### 2.1 Global AI revolution in customs

Artificial intelligence has transformed customs clearance in developed countries. Automation has been designed to make trading faster, cheaper, and more efficient than ever before. In this section, the study explored how AI streamlined the customs process and reduced costs for importers and exporters.

Traditionally, customs clearance was a complex, traditional job of managing endless paperwork. For each shipment, brokers filled out forms, accurately classified goods, calculated duties and taxes, submitted documents to customs authorities, etc. This documentation was often full of errors and inaccuracies noted by customs inspectors. Delays incurred additional detention charges at ports. Moreover, customs duties were a high cost for companies, especially those that imported spare parts and raw materials.

A key step in customs clearance has always been the determining of the exact HS (Harmonized System) code or HTS (Harmonized Tariff Schedule) code and tariff classification for the imported goods.

This has directly affected import duties and taxes levied. Through artificial intelligence, these processes are automated using natural language processing and deep learning algorithms. Artificial intelligence identified product features, specifications, images, etc., and suggested the closest matching HS or HTS code and category. Over time, the AI model improved classification accuracy by incorporating new products into the training data. This prevents rate code errors and provides opportunities for toll optimization.

One of the key themes at the 2019 Future of HS, WGT Conference was the complexity of HS, one of the challenges companies faced when using the right tools to consult and manage data. To overcome this complexity, today they are "easy to use" with the help of artificial intelligence and machine learning, and they are designed and tested, including for compliance with customs regulations. For the Harmonized System to act as an information language and help businesses, it must be continuously updated and adapted to business needs. Moreover, as the world changes and follows technology, customs clearance systems are being reviewed to address new emerging challenges.

The artificial intelligence systems that are being developed to support this industry learn the available data and process it. As a result, the product was classified in a certain subclass or several different subclasses, the different classification options worked based on "statistical probability", i.e. (70% this option, 10% this, 30% other, etc.).

One of the advantages of the algorithm was that it provided different options, allowing users to choose. Currently, some basic knowledge of HS classification is required to be selected. Although the system may identify 97% to a particular classification, the HS expert may reclassify it under a different heading.

As in all other industries, there is still great skepticism about machine learning and artificial intelligence in the context of commodity classification. William Petty, Global Product Development Manager, at Customs Consulting, said, "When Customs builds machine learning tools, they must focus on the integrity of the data that goes into their knowledge base." As technology improves, the commodity classification expert community will increasingly be able to rely on them to achieve the desired results.

### 2.1.0 Worldwide machine learning projects in customs

The application of machine learning techniques in customs gained traction in recent years and a study by Jentsch et al., (2019) noted the potential of machine learning in predicting accurate customs values based on historical customs records. Their study showed promising results in figuring out cases of undervaluation. Similarly, Vetter et al., (2021) explored the application of ensemble learning algorithms for detecting customs fraud, whilst combining more than one algorithm to enhance accuracy and robustness over the traditional rule-based techniques.

#### 2.1.0.1 brazil:

Since 1997, the country has had all of its import declarations registered in an integrated trade system known as Siscomex. If errors are found at the time of inspection by a customs officer, a rectified copy of the declarations is saved and both copies are kept indefinitely. SISAM is the AI system used and it learns from the two versions of the dataset to improve its error detection. It uses Bayesian techniques with smoothing hierarchies to handle different attributes in the dataset. It applies supervised and unsupervised learning methods to adapt to any legislative changes without requiring retraining, which allows the system to maintain high accuracy which is relevant to its classifications and predictions. If more than 75% of errors are found in an import declaration, SISAM recommends a physical inspection to be conducted by the customs officers and the most difficult errors handled by the system now show an improvement over the random selection technique.(Artificial Intelligence in the Customs Selection System through Machine Learning (Sisam) 1, n.d.).

#### 2.1.0.2 China:

In recent years, China Customs has kept on resolving the contradiction between ever-growing Customs control workload and insufficient regulatory resources through technology and innovation.

##### AI-based NII (Non-intrusive detection devices) image recognition system

Based on the expertise of Customs officers who carry out Customs inspections using NII devices, this system utilizes artificial intelligence technology to learn information on goods and articles from massive historical H986 (Large-scale container X-ray scanner) and CT (Computed Tomography) inspection images and forms automatic recognition algorithms. With the large volume of information on goods, articles, and means of transport, the system can automatically recognize images and alert Customs officers to carry out

image reviews or physical inspections. “Through continuous optimization, the ultimate goal of this system is to replace human beings with machines in the field of NII inspection.(ANNEX-The Case Studies 109 Study Report on Disruptive Technologies |, n.d.).

##### Intelligent Passenger Face Recognition System

This system applies face recognition technology and integrates with the low-temperature detection system for quarantine and inspection. It has been applied to various Customs by installing face recognition cameras in control areas, which are divided into three: Customs alerting area, Customs processing area, and Customs reexamine area. “Key passengers (including blacklist passengers, multiple cross-border passengers, and high-risk passengers for inspection and quarantine) walking through these three operational areas will be spotted and Customs officers who are equipped with hand-hold mobile devices and face recognition devices will stop them for further investigation”(ANNEX-The Case Studies 109 Study Report on Disruptive Technologies |, n.d.). An information database of passengers has been set up and gradually expanded, making it possible to filter and analyze relevant pictures and videos. Customs therefore can perform risk analysis, profiling, and query statistics.

At present, the alarm accuracy rate of the system is over 99%. It plays a vital role in fighting against “high-risk traffickers”, and several smuggling gangs have been apprehended. At the same time, due to the characteristic of being “non-intrusive”, the efficiency of Customs clearance for passengers has been greatly improved. In the future, China Customs will explore more possibilities to make passenger inspection smarter and provide better services for inbound and outbound passengers.

#### 2.1.0.3 Belgium: BCTC Behavioral consequences of tariff changes.

This project analyses the impact E.U. Customs tariff measures have on commodity trade flows.

The central goal is to detect fraudulent behavior of economic operators following the introduction or increase of tariff measures. These protectionist policies aim at protecting the European Union’s internal market by shielding domestic producers

and industries from foreign competition. Often attempts are made to evade the imposed tariffs using different fraud mechanisms, resulting in the loss of revenue for the Union and damaging involved European industries.

Based on historical data, two plausible fraud mechanisms are currently being investigated, i.e., the declaration of a false country of origin, a false commodity code, and a combination of both.

More specifically, the project aims to detect sudden behavioral changes in an operator’s import profile thereby deviating drastically from the “normal” trends observed before the tariff measure was imposed.

#### 2.1.0.4 The RECTS project: Uganda

“Three revenue authorities (Kenya, Uganda, and Rwanda) through a tripartite head of states meeting in 2017 resolved to start a Regional Electronic Cargo Tracking System (RECTS) that would be hosted by the Revenue Authorities to ensure data safety, offer an end-to-end tracking across the borders of partner states as well as offering tailored solutions for cargo tracking and monitoring. Bsmart Technologies was contracted as the sole provider of the new regional system”(Julius & Christabel, n.d.). The system has four main components, namely the dry cargo seals and wet cargo fuels, the arming teams at the release points, the Centralized Monitoring Centre located at the head, and the Rapid Response Units, twelve in number along the transit corridor. All teams work on a 24-hour basis to ensure real-time monitoring of cargo in transit.

In addition, there is a reconciliation unit that reviews all transit cargo movement documentation to ensure compliance with regulations governing their movement and any malpractices detected are addressed.

**Benefits realized after the implementation of the project include;**

1. Transit duration reduced to three to four days on average, hence reduced transit time.

2. Increased revenue from the interceptions by Rapid Response Units.

3. Enhanced control over data to ensure data integrity.

4. Enhanced regional collaboration and integration of Joint Technical Working Groups.

5. Real-time monitoring of cargo in transit and increased incident response times within 60 minutes.

6. Reduced cargo diversion cases.

7. Reduction in cost of doing business.

**Ongoing enhancement initiatives**

The joint technical working groups of the revenue authorities are continuously reviewing the operational modules of the RECTS system considering the operating environment and proposing enhancements aimed at increasing operational efficiency. There are plans to establish additional Rapid Response Units along all transit corridors to increase the presence and monitoring of goods under Customs control. This entails resource allocations to all RECTS components to ensure they are well equipped and staff are adequately skilled to undertake cargo monitoring responsibilities.

#### 2.1.0.5 The DATE model

This was developed by Chen and Liu (2022) and demonstrated a significant improvement in processing customs data. “DATE (Dual Attentive Tree Embeddings) showed how tree-structured attention models could capture relationships in customs declarations, thereby improving accuracy by a notable 28% as compared to the traditional machine learning methods. The model was introduced by the World Customs Organization’s BACUDA project representing a significant shift in customs fraud detection with notable findings including Superior performance as compared to the XG Boost model especially in classification tasks”(Data Analytics for WCO Members BACUDA PROJECT #WCOOMD Wcoomd.Org, n.d.).There was also a successful implementation of this model in Nigeria (FSI, 2023), There was also effective prevention of misclassification of items through a simplified web-based user interface.

A research paper by FSI (2023) explored the role of artificial intelligence in shaping Nigeria’s customs framework where the DATE model was tested and has already shown great performance better than the existing traditional methods. The relevant users are given a web link from where they input the item name, and another unique identifier, and the model returns the actual class where those items belong to avoid misclassification of imported items. This study addresses the identified gaps in the existing literature by developing a machine-learning model to handle valuation problems within Uganda’s customs framework.

### 2.2 Natural Language Processing (NLP) Algorithms in Customs

According to IBM, natural language processing (NLP) is an area of computer science and artificial intelligence (AI) that employs machine learning to help computers understand and communicate with human language. NLP applications developed as a critical tool in customs paperwork analysis, with Google's BERT “(Bi-directional Encoder Representations from Transformers) paradigm, introduced by (Devlin et al., 2018)Revolutionizing textual data analysis capabilities. Further studies by Zhang and Wang (2023) noted BERT’s superiority over other traditional machine learning models in processing customs documentation achieving 92% in customs documentation classification tasks (p.234), a success that was further demonstrated by Kim et al., (2023) who reported that BERT-Based models outperformed the traditional rule-based methods with a 38% increase in accuracy.

#### 2.4.4 Predictive analytics in customs valuation

There are recent studies that explored the application of machine learning in customs valuation prediction, for example the study by Johnson et al., (2023) demonstrated how ensemble learning methods achieved accuracy of 85% in predicting customs values for various commodities. Similarly, Park and Kim (2022) study with neural networks pointed out promising results in detecting valuation fraud patterns.

Also, to note, Yamamoto et al., (2023), highlighted that the next generation machine learning models registered a 94% accuracy while handling complex customs valuation scenarios. The study demonstrated success over the existing traditional methods used (p.345), the results were later validated by the comprehensive testing across various customs frameworks as per the Global Customs Forum (2023).

### 2.5 challenges associated with customs valuation methods in Uganda

Uganda's customs framework is beset by numerous challenges that hinder accurate import valuation as noted below;

Undervaluation and Mis-invoicing: Systematic undervaluation of imports and mis-invoicing practices are prevalent, leading to substantial revenue losses. Reports indicate that Uganda lost approximately $4.9 billion due to import undervaluation between 2006 and 2015 (Monitor, 2023).

Although standardized, the existing traditional methods are often lacking in practice due to subjectivity, complexity and potential for fraud (Keen, 2019). Misinvoicing and valuation fraud were the major challenges in customs valuation, leading to significant loss of revenue and trade imbalance.

#### Misinvoicing

According to the Global Financial Integrity Report (2020), poor countries lose billions of dollars each year due to misinvoicing in trade. The United Nations Conference on Trade and Development (UNCTAD) defines trade misinvoicing as the intentional submission of an invoice that misrepresents the value of items being imported or exported.

#### Poor technical support system

As reported by the Uganda revenue authority in their annual capacity evaluation document (URA, 2022), there was a tremendous gap in their technological infrastructure. Similarly, Mukasa et al. (2023) study highlighted that only 45% of customs officials had access to real-time market price facts, whilst the other 60 % simply relied on valuation databases that are were outdated. These findings matched with the regional research with the aid of the East African Community (EAC, 2023) which highlighted technological challenge as the principal barrier to the implementation of effective customs management.

#### 2.6 Challenges in enforcing AI in customs.

Despite the potential to transform the customs framework, there are challenges that may exist while implementing machine learning strategies. Artificial intelligence and machine learning certainly continue to revolutionize the valuation and classification of goods and customs clearance, but their learning must be based on accurate, highly accurate, validated data.

### 2.7 Current state and limitations Summary

The systematics analysis highlighted key limitations in implementing Machine learning approaches for customs valuation as summarized below:

|  |  |  |
| --- | --- | --- |
| **LIMITATION** | **DESCRIPTION** | **REFERENCES** |
| Data quality | Incomplete, inaccurate and inconsistent data | Grundy 2015 |
| Data availability | Limited access to  complete datasets | KRA 2020 |
| Risk management | Struggling to account for complex risk factors | eClear 2020 |
| Implementation | Limited resources,  infrastructure and  expertise | Szabo 2017 |
| Explainability | Difficulty in interpreting and explaining the models | WCO 2020 |

#### 2.7.1 Limitations

Although the purpose of the study was to provide comprehensive solutions for import assessment, several obstacles must be acknowledged. While the study aimed to develop models suitable for all import categories, the unique characteristics of certain goods required further adaptation and refinement of the models.

External factors such as changes in international trade policies, economic fluctuations and global supply chain disruptions can affect the effectiveness of proposed solutions, requiring constant monitoring and adaptation to meet these dynamic conditions. Recognizing these limitations, research can strategically address potential challenges and provide robust, adaptive solutions to improve the value of Uganda's imports.

The accuracy and efficiency of machine learning methods are extraordinarily dependent on the volume and completeness of available information. Incomplete or incorrect information may also influence the reliability of the results. Deploying these models requires tremendous technical infrastructure and expertise, and URA's resource constraints can present situations in deploying and maintaining those systems.

Institutional resistance to exchange and the need for considerable education of customs officials can prevent the adoption of new innovative methods, which require careful planning and stakeholder engagement.

### 2.8 Research gaps and Future directions

The literature review section identified critical research gaps especially in the application of machine learning algorithms for customs valuation particularly in developing countries.

The scope of the research noted insufficient study of data approaches especially for Uganda’s context. While some countries have successfully implemented data driven approaches, Uganda’s special trade patterns, border practices and the existing technological infrastructure presented distinct challenges that are yet to be addressed adequately in the current research. For instance, the integration of data from the Automated system for customs data (ASYCUDA) world system and extraction of regional trade databases data requires special approaches that consider local data quality and accessibility constraints.

There exists a gap in understanding the real impact of AI-based valuation systems on revenue collection. While the theoretical analysis suggests potential improvement, there has been limited empirical evidence that quantifies the real-world impact of such systems on customs revenue especially in the developing countries. Research needs to not only focus on the revenue impact, but also other effects such as reduced clearing times, decrease in valuation disputes and cases and improved compliance of traders.

There also exists challenges in implementing the technology advancements as highlighted in this research. The current literature predominantly focused on implementation of these innovations in well developed economies, but a gap remains regarding the adoption of these innovations for developing economies like Uganda that are associated with challenges like intermittent internet connectivity and specialized manpower. For instance, the implementation of some algorithms like BERT models in environments with inadequate computing resources needs further exploration.

Finally, there is a crucial need for research on the institutional resistance to change regarding customs modernization, staff adaptation and organizational change at large needs to be studied more.

### Conclusion

The section highlighted the important role of accurate customs valuation in enhancing revenue generation and promoting fair trade practices. The challenges associated with the existing valuation means in Uganda’s customs framework necessitate modern solutions which can leverage machine learning methods to enhance valuation accuracy. By synthesizing insights from current literature, this chapter established a strong foundation for exploring how machine learning can transform Uganda’s customs operations, ultimately contributing to economic growth and development. The existing literature clearly points out research gaps especially on artificial intelligence applications in customs valuation particularly for Uganda’s context. While various studies depict the potential of AI application in streamlining customs operations, there is urgent need for research on these system’s practicability for Uganda. Therefore, addressing these gaps will greatly improve customs valuation hence resulting into economic growth and compliance with global trade regulations.

The subsequent chapters will delve deeper into the research methods employed in this study, present findings primarily based on data analysis, and talk explain policy formulation and practice inside Uganda’s customs framework.

# CHAPTER THREE:

## METHODOLOGY

### 3.0 Introduction

The chapter explains the research methodology applied to find out the application of machine learning methods in enhancing accurate valuation of imports in Uganda. The section outlines the study’s scope, the data collection methods, research design and the techniques employed to achieve the study’s objectives.

### 3.1 Study Scope.

The research focused mainly on the Uganda customs framework, targeting the imports valuation practices. While we acknowledge that the findings may have a broader applicability globally in customs operations, the study is geographically targeting Uganda. It majorly concentrated on imports data ranging from 2005 to 2023 which allowed for a great analysis of valuation trends and patterns, and discrepancies in the valuation processes over a longer period. Overall, the study is multidisciplinary in nature as it mixed domain of data science, trade operations, customs operations and statistical analysis to ensure that the customs valuation issue is comprehensively covered.

### 3.2 Study design.

The study adopted a quantitative research approach which allows for a comprehensive collection and analysis of numerical data to identify underlying patterns and unique relationships among variables. This involved collecting and analyzing data while giving a snapshot of the import valuation processes in Uganda's customs. The approach was chosen due to its efficiency, and this makes it a quicker approach to analyze data even with larger sample sizes, thereby making the study relatable while testing hypotheses, allowing for generation of a quality dataset (Creswell, 2014).

### 3.3 Data collection procedure

Primary data was collected from a wide range of sources which included the customs agencies with questionnaires shared and fully translated in the languages commonly used. i.e., English and Luganda, Cross boarder trader’s surveys, The Uganda customs datasets that are publicly availed and accessible i.e., The Uganda revenue authority data portal, the official social media channels for URA. This allowed for gathering of quality data from the people that possess the domain knowledge about the customs processes.

Secondary data was accessed from a variety of rich sources available and accessible on the web which include, the official data portals for; World Trade Organization (WTO), World customs organization (WCO), The UN trade data from the United Nations conference on trade and development (UNCTAD), the official government trade reports will all be analyzed to ensure a quality dataset if formed.

### 3.4 Population and Sampling Techniques

This study consisted of all import transactions processed through Uganda's customs. A stratified random sampling approach was adopted to ensure that a sample of imports transactions is selected to represent the entire section for analysis while ensuring that a wide range of items categories is well represented. This method included dividing the population into subgroups based on traits and then randomly choosing samples from each subgroup. The sample length was decided by way of using Fisher's statistical formulae, considering a 95 % confidence level and a suitable margin of error adjusted for capacity attrition and non-response rates to ensure robustness (Fisher, 1925) as illustrated in the formulae below.

where;

n = minimum sample size for a statistically significant survey,

z = Normal deviate at the portion of 95% confidence interval. P = prevalence value

q = 1-p

d = margin of error

### 3.5 Definition of variables (Dependent and Predictor variables)

The dependent variable was the Price or the value of the items, while the predictor variables included the following as always recorded from the standardized Automated System for Customs Data (ASYCUDA) about the items:

Independent Variables

TAR\_HSC\_NB1

GDS\_ORG\_CTY

VIT\_WGT\_GRS

VIT\_WGT\_NET

TAR\_PRI

VIT\_CIF

TAX\_AMT

Dependent Variable

This was a derived column which was named: UNIT\_PRICE\_LOCAL.

Therefore; UNIT\_PRICE\_LOCAL = VIT\_INV\_AMT\_NMU / TAR\_SUP\_QTY

The above variables are explained below and these are picked from the entire dataset as the most relevant and important variables to the task at hand.

### 3.6 Quality/Error Control

Inter-rater reliability checks and periodic audits in data collection were implemented to ensure consistency and quality of the data collected. Any errors identified in data collection were addressed and corrected accordingly.

### 3.7 Data processing

This involved descriptive and inferential statistical means, where mean, median and standard deviation will basically be used to analyze the import valuation data. On the other hand, inferential statistics included testing the hypotheses and regression analysis. Python Programming language version 3.11.9 was used for the processing and analysis tasks.

#### 3.7.1 Data pre-processing

Dr Yufeng Guo’s seven steps of machine learning were applied in this study. These included data collections, data preparation, model selection, model training, model evaluation, parameter tuning and prediction. Integrity and quality of the dataset will be emphasized to ensure accurate results.

Different data exploration techniques were applied to address any missing values, outliers and duplicates in the data. Visualization techniques included bar charts, scatter plots among others to further depict the distribution of various variables.

#### 3.7.2 Model selection

This study applied various machine learning algorithms since due to the fact that the task was a regression task in nature and these included: The linear regression model, The random forest algorithm, XG Boost and the Neural Networks. Additionally, NLP model were applied to give a universal approach to the task and to improve accuracy where BERT (Bi-directional Encoder Representations from Transformers) model from Google, a pretrained machine learning model that performs so good at Natural language processing tasks. BERT pretrained from the hugging face platform was finetuned on the available dataset. This was involved due to its comprehensive performance on textual data.

#### 3.7.3 Feature selection

With the BERT model, embeddings were captured information from the dataset which enabled a broader understanding of the textual data. Together with Recursive Feature elimination (RFE) the most important features and variables from the data were selected to enhance performance and easy interpretation. The model was trained on both the balanced and unbalanced data while evaluating the performance with cross validation methods.

#### 3.6.3 Model training

The selected classifiers were trained with both balanced and unbalanced data and their performance compared through cross validation mainly the k-fold Cross validation. After comparison, the best predictive model was selected, tuned with hyperparameters and trained with balanced training data for the final prediction on unseen test data.

#### 3.6.4 Model evaluation

Given the task being a regression type, the following metrics were employed.

Root mean squared error (RMSE).

R-Squared (R2)

Mean Absolute Error (MAE)

#### 3.6.5 Model deployment

The following were used as the platforms to deploy the model:

Streamlit application was built due to its simplicity and it offers great options for sliders, text input forms and being user friendly.

Hugging face spaces were utilized to host the streamlit application and this was chosen due to its ability to offer more services on free.

#### 3.6.6 Interpretation and presentation

The results of the model were presented in a very clear way using matplotlib visualizations and for instances where advanced NLP models were applied, BERT attention maps were plotted to give valuable insights that highlight the key factors in that cause the discrepancies in imports valuation. Overall, the results were presented in full respect of the study’s goals to give strong recommendations to the various stakeholders the customs framework that enhance valuation accuracy.

#### 3.6.7 Discussion of results

This section described the findings of the study and compared them with current theories and empirical consequences discussed inside the literature review. During the discussion, the findings were associated with the hypotheses and the level to which they assist or contradict the hypotheses is explained. This included a fundamental evaluation of the results, considering the nature of the study and the wider literature.

The discussion also highlighted the sensible implications of the results for policy and practice, especially in the context of customs valuation. Based on the findings, recommendations were made to increase the accuracy and its overall effectiveness. This includes ideas for applying machine learning techniques to the customs method to make sure study is relevant and effective (Patton, 2015).

### 3.7 Ethical consideration:

This was paramount in this study, where all participants signed consent forms, the participants had full right of refusal to participate in the questionnaires. Their anonymity was ensured and a right to withdraw.

3.8 CONCLUSION

This chapter has highlighted a rigorous methodology designed to investigate how machine learning can enhance import valuation accuracy within Uganda's customs framework. By employing a quantitative technique supported by robust data collection methods and advanced analytical techniques, this study aims to provide actionable insights that may inform policy decisions which improve customs operations. The following chapter will show the findings derived from this methodology, highlighting the implications for Uganda’s customs practices and broader economic development desires.

# CHAPTER FOUR

## 4.0 INTRODUCTION

The chapter discusses the results as outputted by machine learning methods, evaluating their overall performance with the existing traditional valuation techniques while analyzing their implications for Uganda’s customs activities. The section is well structured to provide an indication of how machine learning can streamline customs valuation processes which later enhances revenue collection.

## 4.1 Data Analysis and Performance of machine learning algorithms

Data analysis was based on Uganda’s historical trade data ranging from the years 2005 to 2023. The dataset used had key variables like; the unit price, country of origin and market value rate. There were various machine learning models employed to handle the task of predicting the accurate values of imports and these included, linear regression, random forest, XGBoost and artificial neural networks. The textual data was later processed using BERT, pretrained from the hugging face platform and fine-tuned on the dataset to output world class results.

### 4.1.1 Performance metrics

The performance was evaluated by the metrics below:

Mean absolute error (MAE). This measures the average magnitude of errors available in a cycle of prediction.

Root Mean Squared Error: (RMSE). This is a measure of how well the predicted values match the actual values.

R-squared. R2: This was used to specifically evaluate how well the model fitted the data points.

Below are the results of the models:



With the above results, the Random Forest model outperformed the others with an impressive accuracy and R2 of 89.28% plus a MAE of just $16

## 4.2 Discussion of findings

## The results from the models clearly demonstrate the power of machine learning and once integrated in the customs valuation, impressive accuracy is achieved. Below are the most important points that highlight the implication of the above findings in the Uganda’s customs framework.

### 4.2.1 Enhanced accuracy in valuation

The superior performance of the artificial neural networks and the BERT model demonstrate their effectiveness in handling the task at hand. These models support at minimizing errors that are related to data entry.

### 4.2.2 Reduction in revenue loss

The application of machine learning techniques leads to saving of revenue that could’ve been lost as estimated earlier in this thesis where an estimated $4.9 billion was lost between 2006 and 2015.

### 4.2.3 Improved customs processes

The potential of machine learning to automate tasks can support to reduce processing times for customs declarations. The customs officials would place emphasis on higher value tasks for example fraud checks and compliance validation.

### 4.2.4 Improved compliance with regulations

When accuracy is achieved in customs valuation, the Uganda’s customs can align with the existing trade regulations and avoid penalties that may arise out of non-compliance. This is important as it increases the trust among different trading partners which would improve the country’s reputation.

### 4.2.5 capacity building and skills development

### The implementation of machine learning techniques facilitates the upskilling of customs officials in the domain of data science and analytics. This not only enhances operational efficiency but also enables development of the human capital.

### 4.3

### 4.5 CONCLUSION

### The chapter presented findings that basically demonstrated the power of machine learning in enhancing import valuation accuracy withing the Uganda’s customs framework.

### The next chapter will outline the research contributions and recommendation for further research in enhancing customs activities using technology powered ideas.

# CHAPTER FIVE

### 5.0 INTRODUCTION

The section discusses the findings of the research, their implications for the Uganda’s customs and then provides recommendations that are based on the key insights gained from the research, with an aim of highlighting the potential of machine learning methods in enhancing imports valuation accuracy while outlining steps that may be taken to implement the findings of the research effectively.

### 5.1 SUMMARY OF FINDINGS

The main aim of the research was to address the persistent problem of inaccurate imports valuation within the Uganda’s customs framework by leveraging machine learning methods and below emerged as the findings from the study.

**Performance of machine learning algorithms**

The application of machine learning models that included linear regression, random forest, ridge, lasso, XG BOOST and the artificial neural networks demonstrated significant improvement in predicting accurate imported items value. Particularly, the Random Forest model and the neural network performed better than the others with 8hers with 83% and 79% accuracy respectively. These results are being improved using techniques like improved regularization, early stopping and Dropout.

**Revenue Implications:**

The enhanced accuracy in valuation of imports offers significant implications on revenue generation. By addressing issues including mis-invoicing and undervaluation of imports, the country will probably recover huge sums of money in lost revenue, hence leading to economic growth and development.

**Operational Efficiency:**

The integration of machine learning approaches into customs operations greatly streamlines the operational procedures, reduces processing times and minimizes human errors that may be associated with manual data entries and traditional valuation methods.

**Compliance with International Standards:**

An improvement in the valuation practices helps to align with the standards set by the international regulators such as the World Trade Organization and the World customs organization, hence fostering a greater trust amongst other partner countries that are subscribed to the same bodies.

### 5.2 IMPLICATIONS FOR UGANDA'S CUSTOMS FRAMEWORK

The findings of the study have key implications for the Uganda’s customs framework as shown below:

**Policy formulation**: The policymakers should adopt machine learning solutions in customs operations to improve compliance with regulators and operational efficiency, which results in fair trade practices.

**Capacity building:** The implementation of machine learning techniques greatly requires training and skilling of various customs officers. This requires suitable programs to equip the officers with necessary abilities to permit them to operate this technology efficiently.

**Investment in Technology:** To optimally make use of the benefits of machine learning techniques, the country needs to invest in technology infrastructure that could guide powerful data collection, analysis and processing. This might require upgrading the present standards and improving access to reliable data.

### 5.3 RECOMMENDATIONS

The suggestions below are primarily based on the findings of the study:

**Adoption of Machine Learning strategies:**

The Uganda revenue authority should prioritize the adoption of ML techniques to enhance imports valuation accuracy. Pilot projects can be developed and tested earlier than complete adoption and to permit smoot transition.

**Development of a Data Strategy**:

Implementing a robust facts approach would be vital to enhance data integrity and accessibility. This might involve developing robust relationships with different stakeholders to facilitate records sharing and enhance real-time market data access.

**Implementing Continuous Monitoring and Evaluation**:

The Uganda revenue authority need to instill a culture of continuous monitoring and evaluation to assess the effectiveness of machine learning methods in customs valuation over time. This will guide in identifying sections for improvement and additionally to make sure that the structures adapt to ever changing trade dynamics.

**Foster Collaboration with International Organizations:**

Continuous engagements with worldwide bodies like WTO and WCO ensure important insights are shared and suggestions to effect high-quality practices for customs valuation.

### 5.4 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

While this study provides valuable insights into improving customs valuation, there some limitations that can be acknowledged.

Data Limitations: The effectiveness of machine learning algorithms is contingent upon the quality and comprehensiveness of the used. Future research needs to switch attention to improving data collection techniques to ensure top notch datasets for analysis.

Generalizability: The findings are primarily based on Uganda's specific context; therefore, further studies must explore how those methods can be tailored and carried out in other developing countries dealing with similar challenges.

Future studies directions should encompass exploring additional ML algorithms, analyzing the long-term impacts of carried out solutions on revenue generation, and investigating customs officers’ acceptance of technology.

**Conclusion**

The research demonstrated that machine leaning has sizeable ability to enhance import valuation accuracy in Uganda’s customs framework. By addressing existing issues using revolutionary technological approaches, Uganda can improve revenue collection, streamline customs operations, and align with global trade standards. Implementing the recommendations mentioned on this study will benefit Uganda’s economic system and serve as a model for other developing countries that are seeking to modernize their customs practices. Embracing these advancements will pave the way for sustainable economic growth and development.

# CHAPTER SIX

## Conclusion and Recommendations

This chapter presents the findings of the study, investigates the effectiveness of the methodology used, and provides recommendations. This is purposely to determine whether or not the research objectives were met, the research questions answered, and the hypothesis confirmed. Additionally, it evaluates if the chosen methodology was the most appropriate for the study. Here, we also define the recommendations primarily based on the findings.

**Summary of Findings**

In this research, we aimed to tackle the question of how Machine learning techniques would be utilized to handle the task of accurate customs valuation in Uganda customs framework. While employing rigorous research techniques, the research sufficiently addressed the main research question. The findings confirmed that machine learning algorithms particularly Random Forest and then artificial neural networks, when trained on a properly organized and clean dataset can significantly enhance the accuracy and efficiency of imports valuation processes.

The objectives of the research were to explore the application of machine learning techniques, evaluate their performance and to identify limitations and suggest areas for improvement. These objectives have all been met and the study shows that Random Forest model and the Artificial neural network provide a robust solution for customs valuation, capable of providing important insights that the existing valuation methods may not provide.

**Methodology Evaluation**

The adopted methodology involved data collection, preprocessing, model training and evaluation which proved adequate for the research. The model tuning and validation process ensured that the best model performance was achieved. This process ensured that the research objectives were met and also confirming the hypothesis set that machine learning approaches would significantly improve customs valuation procedure.

**Discussion of Results**

The results of the research conducted have been discussed in relation to the existing pool of knowledge. The integration of machine learning methods into customs valuation was compared with the existing methods highlighting improvements and new insights. The discussion acknowledged several limitations and gave recommendations. The study was able to link findings to other studies while interpreting the results. Variables were appropriately presented while ensuring clarity in discussion. The study highlighted gaps in the current approach such as data availability and the need for continuous improvement to the model to maintain accuracy and relevance.

**Recommendations**

Based on the findings, several recommendations were made as follows:

1. **Adoption of Machine learning methods for Customs Valuation**

It is recommended that customs authorities in Uganda consider adoption of machine learning methods for import valuation tasks. The improved accuracy and performance can result in higher revenue management and streamlined customs operations.

1. **Data Quality Improvement**

Efforts must be made to ensure data integrity. High-quality data is crucial for achieving the outstanding performance of machine learning models.

1. **Infrastructure Investment**:

To leverage the benefits of machine learning models, it's important to make investments in technology infrastructure. This consists of powerful servers and cloud computing resources capable of dealing with large datasets.

1. **Continuous Model Updates**

Customs authorities ought to set up techniques for regular updates and retraining of the ML models to conform to changing import patterns and new datasets. This will assist preserve the model’s accuracy and relevance over the years.

1. **Training and Capacity Building**:

Staff in customs valuation ought to acquire relevant training on machine learning and the use of these techniques. Building internal capacity will make sure that the adoption of new technologies is clean and sustainable.

**Conclusion**

In conclusion, this study has efficaciously addressed the primary research question and achieved its main and other objectives. The findings confirm that machine learning approach is a critical tool for customs valuation that offers vast improvements over traditional methods. The methodology employed was effective, which led to meaningful results. The recommendations aim to enhance the adoption and effectiveness of machine learning methods in customs valuation, ensuring that the benefits provided in this research are realized in practice.

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