



**MODERNISING PRISON SYSTEMS LEVERAGING IOT EM DEVICES: A CASE
STUDY OF THE GHANA PRISON SERVICE**



Draft

ARDEN UNIVERSITY

Awarding Body:
Arden University
Programme Name:
Data Analytics and Information Systems Management
Module Name (and Part if applicable):
Research Project
Assessment Title:
Modernising prison systems leveraging IoT EM devices: A case study of the Ghana Prison Service
Student Number:
STU65657
Tutor Name:
William Murray Baker Morrison
Word Count:
15681
Please refer to the Word Count Policy on your Module Page for guidance

DECLARATION

I hereby declare that this dissertation was entirely an independent work under the supervision of Mr. Williams Baker Morrison in partial fulfilment of Master of Science degree in Data Analytics and Information Systems Management. All externally sourced materials are duly acknowledged.

I am also declaring neither this project nor any part thereof has been submitted else where for the award of any degree.

Arden University can therefore use the document in whole or part for further research or academic work without restriction of any kind.

Supervised by:

William Baker Morrison

Lecturer

Arden University

Submitted by:

Bawa Abdul-Razark

STU65657

Arden University

ACKNOWLEDGEMENTS

I wish to thank my supervisor William Baker Morison for his guidance and unflinching support throughout this research. He contributed in diverse ways in helping shape the content of this dissertation. His meticulous reviews and recommendations put me on course to successfully finalise the dissertation.

Recognition is due to the Director-General of the Ghana Prison Service Patrick Darko Missah for granting me unfettered access to prison resources and materials to facilitate this research. Many thanks to the Head of IT at the Ghana Prison Service Charles Clegg for his cooperation and collaboration at every stage of the research process for data access. Without his generous effort and support, this document could not have been produced.

I wish to acknowledge with appreciation the effort made by Ebenezer Essel Mensah for submitting the questionnaire at various prisons in the southern part of Ghana to Fastrack the pilot studies of some selected prisons in Ghana

Finally, I want to thank my wife Samira Adam and kid Wumpini Abdul-Razark for their support and encouragement in my difficult moments during the process of completing this dissertation. I will forever remain grateful for all their support and encouragement.

ABSTRACT

The purpose of this study is to explore how the Ghana Prison Service could deploy a miniature IoT EM technology as alternative in managing non-custodial sentence focusing on petty offenses. This has become imperative due to challenges of overcrowding ingrained in brick and bar prison, disproportionate use of prison for petty offences, high administrative and infrastructural cost incurred in managing prisons, emergence of pandemic such as COVID 19 among others.

The research strategies considered in this study were mixed methods which includes case study, action, and desktop research. To achieve the research objectives, the Ghana Prison Service served as a case study to help appreciate and understand the nuances and challenges of overcrowding attributed to petty offences and action research strategy was explored to help **provide immediate** pragmatic reforms to overcrowding challenges leveraging IoT EM options.

In all, the findings revealed 8 offences could be reclassified as petty offences which would impact 4700 inmates constituting 40.6% of the total inmate population. Imposing non-custodial sentence option for the 4,700 inmates would reduce the current prison overcrowding rate from 35.5% to excess prison capacity of 0.13%. In effect, prisons would have excess capacities to hold hardened criminals.

This research has the potential to advance knowledge in location intelligence as emerging areas in crime prevention since the use of IoT EM option could provide geospatial data to help in tracking location of offences more efficaciously. Petty offenders will only lose their location privacy and can therefore leave a normal live under strict monitoring and supervision. Those who are breadwinners can continue to work and cater for their families to avoid a situation where helpless dependents resort to dubious means for survival which has the tendency to amplify crimes in our societies.

One of the key limitations in this study was the lack of a cut off period for the data used. The variation in prison population is a daily, weekly, and monthly phenomenon. Therefore, to have a comprehensive study of the domain, the data used must be within a certain time frame. However, in this study the data used covered both 2018 and 2021 which has an impact on the totals as reported. However, the impact on the findings was minimal.

Table of Contents

LIST OF TABLES AND FIGURES.....	vii
1.0 INTRODUCTION.....	1
1.1 RATIONALE.....	4
1.2 GHANA PRISON SERVICE AS A CASE STUDY.....	4
1.3 RESEARCH OBJECTIVES	5
1.4 IMPORTANCE OF THE STUDY	5
1.5 SCOPE AND LIMITATION	6
1.6 DISSERTATION STRUCTURE.....	6
2.0 LITERATURE REVIEW	7
2.1 INTRODUCTION	7
2.2 ORIGIN OF PRISON SYSTEMS AND INTERVENTIONS TO ADDRESS OVERCROWDING.....	7
2.3 USE OF ‘TECHNO CORRECTIONAL’ MEASURES	8
2.4 IMPACT OF ELECTRONIC MONITORING ON RECIDIVISM.....	10
2.5 POTENTIAL IMPACT OF IOT EM MONITORING ON PREDICTIVE CRIME AND PREVENTION USING GEOSPATIAL DATA.....	11
2.6 SUMMARY	11
3.0 METHODOLOGY AND METHOD	12
3.1 INTRODUCTION	13
3.2 RESEARCH PHILOSOPHY	13
3.2 RESEARCH STRATEGY	13
3.3 RELIABILITY AND VALIDITY	14
3.4 DATA SELECTION AND COLLECTION	15
3.5 DATA PROCESSING AND ANALYSIS.....	16
3.6 ETHICS AND BIAS	17
3.7 LIMITATIONS.....	18
4.0 RESULTS AND DISCUSSION.....	20
4.1 INTRODUCTION	20
4.2 INMATES DEMOGRAPHICS AND PRISON TYPES	20
4.2 INVESTIGATE THE UNDERLYING CAUSES OF OVERCROWDING	23
4.3 PATTERNS AND TRENDS OF CRIMES ACROSS REGIONS IN GHANA OVER TIME.	27

4.4 PREDICT GROWTH OF PRISON POPULATION FOR TIMELY INTERVENTION TO AVOID OVERCROWDING	34
PATTERN AND TRENDS OF PRISON ADMISSION IN GHANA	36
4.5 PROPOSED IOT ELECTRONIC MONITORING SOLUTIONS	40
4.6 ESTIMATE OF COST BENEFITS ANALYSIS OF THE PROPOSED IOT EM DEVICE	41
5.0 CONCLUSION ANDRECOMMENDATION	45
5.1 INTRODUCTION	45
5.2 GENERAL CONCLUSIONS	45
5.3 RESEARCH OBJECTIVES CONCLUSIONS	46
5.4 RECOMMENDATIONS	48
5.5 ERRORS AND LIMITATION	49
5.6 RECOMMENDATIONS FOR FURTHER STUDY	50
REFERENCES	51
APENDICES	55
Appendix I	55
Appendix II	57
Appendix III	58
Appendix III	59

LIST OF TABLES AND FIGURES

Tables

Table 3. 1: Summary of Data Sources	17
Table 4 1 : The number, types, and risk classification of Prisoners in Ghana.....	22
Table 4 2: Crimes rate across regions	27
Table 4 3: Average monthly prison admission rates.....	35
Table 4 4: Cost estimates of current prison management and proposed IoT solutions	43

Figures

Figure 4 1: Prison Population by Gender.....	20
Figure 4 2 The graph below shows the different age groups behind bar in Ghana.	21
Figure 4 3 Prison classification and the level of overcrowding.....	22
Figure 4 4 Ribbon Chart highlight specific facilities facing overcrowding challenges.....	34
Figure 4 5 Underlying Reasons Causing Overcrowding	23
Figure 4 6 Overview of prison overcrowding in specific facilities and underlying causes.....	25
Figure 4 7 Classification of Offences (Petty and Non-Petty Offences).....	24
Figure 4 8 Potential Impact of IoT EM intervention on overcrowding	27
Figure 4 9 Bubble chart overview of pattern of crimes across regions in Ghana.....	28
Figure 4 10 Heat Map of all offences across regions in Ghana	29
Figure 4 11 Overview of offences across different geospatial coordinates (By latitude, longitude, and Crime Frequency).....	30
Figure 4 12 Regression analysis of average monthly prison admission rate from 2015 to 2018	Error! Bookmark not defined.
Figure 4 13 Proposed Wristlet Electronic Monitoring Device	40
Figure 4 14 Component Diagram of the proposed prison concept	41
Figure 4 15 Cost estimates of IoT EM option juxtaposed with extra cost of incarcerating of petty offenders	43

1.0 INTRODUCTION

This research seeks to explore how the Ghana Prison Service could deploy a miniature Internet of Things (IoT) Electronic Monitoring technology solution to initiate reforms in the management of its brick and bar prison systems. The focus of the IoT EM solution is to facilitate non-custodial sentence options for petty offenses as part of efforts towards depopulating Ghana's Prison System to address overcrowding.

The concept of brick and bar prison had been in existence since the 19th century and homogenously adopted across the globe as the mode of punishment for offenses. However, the challenges of prison overcrowding coupled with Governments budgetary constraints in investing in prison infrastructure, call for a new way of thinking in prison management and administration. The United Nations Office for Drug and Crime (UNODC, 2013) defines overcrowding as a situation where the number of prisoners exceeds the official prison capacity. This challenge has left most prison systems with serious inhumane conditions whereby people are cramped in prison with little space to sleep, sit, move, and face serious unhygienic and nutrition challenges, among others. One of the key contributors to prison overcrowding underscored by Commonwealth Human Rights Initiative (CHRI, 2018, p6) is the incarceration of petty offenders and define petty offenses as 'minor offenses for which the punishment is prescribed by law to carry a warning, community service, a low value fine or **short-term imprisonment, often for failure to pay the fine**. The study undertaken by CHRI acknowledged the fact that most of the petty offenders are poor and the vulnerable group in society and are usually unable to pay the fines imposed on them resulting in their incarceration. Instances, where these incarcerated petty offenders are the breadwinners in their families in areas where there are little or unavailable social support systems, expose their dependent relatives to hardships and could force them to resort to dubious means (e.g., prostitution, petty theft, etc) for survival. This situation could create a vicious cycle of amplifying crimes instead of limiting crimes in our societies. This challenge was highlighted in the handbook of the UNODC (2013, p.15) as "she was arrested in 2003 and sentenced to eight years in prison. She says: "...When they sentenced me, and it's the same for every woman they sentence, they not only sentence the person who committed the crime, they also sentence their family, they also sentence their children. [...] [Authorities] don't realize that they want to get rid of crime, but they are the ones promoting it because if they [the children] are left alone... what can they do? Go and steal... my daughter would become a prostitute, my son would become a drug addict, deal drugs, sell drugs". This statement throws more light on the fact that incarceration of some of these petty offenders with dependents could amplify crimes in our societies.

Another worrying trend are instances where incarcerated petty offenders meet hardened criminals and get influence negatively. A situation that could also create a vicious cycle of amplifying crimes instead of prisons serving as a home for reformation and rehabilitation. According to the CHRI (2018, p.33) "criminalization and possible prosecution may lead to other crimes... people have returned from prison far worse than they left". The time has come for the world to deemphasize

incarceration for petty offenses and other forms of minor crimes and rather explore alternative forms of punishment outside the brick and bar prison leveraging IoT smart prison solutions with potential for big data innovations.

According to the International Committee of the Red Cross (2011) which conducted over 5000 visits to 1800 detention centres, overcrowding was one of the major challenges witnessed in most prisons. This claim was buttressed by the Penal Reform International (2020) which states that prisons in over 124 countries exceeded their maximum occupancy rate, with 23 national prison systems at more than double their capacity. This lends credence to the fact that prison overcrowding is a global phenomenon that requires that pragmatic reforms are put in place as part of an effort towards achieving Sustainable Development Goal target 16.3 and 16.3.2 to address challenges of unsentenced detainees as a proportion of the overall prison population (The Danish Institute for Human Right, ca 2021). The challenges of overcrowding cannot be underestimated since in some cases it could lead to a life-threatening situation and can even result in death. **This claim is supported by UNODC (2013, p13) who stated that in low resource countries where the budgetary allocation for prisoners' basic needs such as food would hardly change to meet the needs of the growing population. A situation they believe could compromise prisoner health resulting in death due to malnutrition in some instances.** It is therefore imperative to adopt serious reforms to avoid or address prison overcrowding challenges focusing on petty offenders.

A study conducted by Reno et al (2000) revealed that overcrowding in prison when considered in simple terms has two main dimensions which are mainly the rate of admission into jails and length of confinement (sentencing regime). These two key dimensions impact the use of brick and bar prison capacity leading to overcrowding. Another major contributor is the case management processes where different actors interface at different decision points leading to sentencing or freeing a person. This third option has been the focus of many reforms across the globe. However, most prison reforms that seek to concentrate more on the case management process are usually short-lived. Even though studies have shown that the actions and inactions of front-end players in the justice delivery process contribute significantly to overcrowding, this study seeks to focus on empowering the back end (prison administrators) in dealing with the situation.

Whilst some countries have taken steps to remodel the 19th-century prison system, other countries are stuck with the old brick and bar prison concept with little or no innovative reforms. In Ghana, even though the management of the prison system has improved over the years, the challenges of prison overcrowding are pervasive in some of the prisons. According to the POS foundation (ca.2020), as far back 2006, the then-Attorney General, Hon. Joe Ghartey was inundated with several petitions from the prison service on the alarming rate of overcrowding in Ghana's prison system. A situation which resulted in the formation of the Justice for All program (JFAP); a mobile in-prison special court sitting as part of measures to decongest the prison population. Although this intervention has yielded some positive outcomes by cutting down drastically the number of remand prisoners, the challenge of prison overcrowding is far from over. A recent study undertaken by Acquah et al (2018) revealed that the prison population of the Ghana Prison Service

had increased to 14,417 and overcrowded by 45.5% against the authorized holding capacity of the prison. This situation exposes the prison systems to human rights abuses and other challenges. At a multi-stakeholder conference organized in 2018, the former Chief Justice of Ghana, Her Ladyship Justice Sophia Akufo called on key state actors and partners to adopt more innovative non-custodial sentencing reforms to help deal with the current prison overcrowding challenges (Business Ghana, 2018). The latest to add his voice to this important issue was the President of the Republic of Ghana, who admitted that the conditions within Ghana's prison system were dehumanizing and gave his assurance to roll out a program to help decongest Ghana's prison population (Modern Ghana, 2020). One of the key interventions proposed by stakeholders was the construction of new prison facilities. However, a study by Reno et al (2000) revealed that the construction of prison facilities to address overcrowding is only a short-term solution that imposes an extra burden on tax revenue due to the structural and administrative cost incurred. The idea of new prisons and the administrative staffing needs are even more unbearable to pursue due to the pressure faced by Governments from other equally important and competing national interests and programs across various sectors of the economy. The choice to site prison at a particular location within emerging smart cities is also a difficult one. These challenges certainly call for smart and sustainable innovative prison reforms leveraging IoT electronic monitoring options with the potential for big data innovations.

The brick and bar prison systems have not been spared from the challenges of the COVID 19 pandemic. Malloy et al (2020) state that over 240,000 people in prison across 110 countries have tested positive for COVID-19 to date just seven months when the pandemic was declared. A lot of prisons are still struggling to find ways to prevent the pandemic. In Ghana, for instance, the Ghana Prison Service proactively took steps by freeing 794 prisoners in the wake of the COVID-19 pandemic (Abu-Bashar, 2020). These challenges further provide a more compelling reason why alternative prison sentence options must be explored to safeguard the life of prisoners within the penitentiary facilities- particularly petty offenders. This is especially important since ultimately, most of these inmates would be freed to reintegrate into the larger society and if care is not taken, they could spread some of these communicable diseases.

Because of the challenges ingrained in the brick and bar prison system, this study seeks to explore alternative miniature IoT tamperproof technology solutions in managing petty offenses as part of an effort towards addressing overcrowding in Ghana's Prison System. The scalability of the technology and the potential to generate geospatial data to draw insight into the pattern of crime could eventually lead to smart prison solutions across the globe. **One of the critical contributions to existing knowledge is the potential to leverage on location intelligence (geospatial data) as further advancement in social sciences to effectively deal with crime.**

1.1 RATIONALE

The purpose of this research is to explore how the Ghana Prison Service could deploy miniature IoT EM Technology as an alternative in managing non-custodial sentences focusing on petty offenses. This has become necessary because of the challenges of overcrowding ingrained in the use of brick and bar prisons coupled with the high administrative and infrastructural costs incurred in managing prisons. Also, the disproportionate use of incarceration on petty offenders does not help in reducing crime but could rather worsen the situation. Therefore, the alternative use of IoT electronic monitoring option could help avoid this situation and by extension, help reduce crimes in our communities.

Again, the emergence of a pandemic such as a corona strongly requires the world to consider reforms in prison management where prisoners are crammed together which exposes them to a lot of danger. This and many other reasons justify why this research is extremely important and timely.

1.2 GHANA PRISON SERVICE AS A CASE STUDY

In Ghana, the concept of incarceration as a form of punishment dates to 1800 when the administration of the then fort of the gold coast was in the hands of the Committee of merchants under the Chairmanship of Captain George Maclean (Ghana Prisons Service, Ca. 2020). This system of prison was later formalized and adopted as a mode of punishment for crime and the Ghana Prison Service mandated by law through Article 205 (1) (2) of the 1992 Constitution of the Republic of Ghana to hold persons committed to custody and maintain internal security and safety. In discharging its responsibility, the brick and bar prisons are the options used for incarcerating offenders.

Even though the brick and bar prison model has since expanded slowly and increased to 46 across the country with a significant number of model prisons, there have not been any major reforms particularly in the use of technology to boost its management and administration. The lack of technology reforms coupled with inadequate investment in infrastructure due to limited budgetary constrain has left the prisons systems with a myriad of problems such as overcrowding and human rights abuses. **According to Penal Reform International (ca. 2020)** which states that prison overcrowding is one of the major challenges across the globe and arguably the single biggest challenge facing the prison system and, in some cases could pose a life-threatening consequence. The challenges of prison overcrowding are pervasive in the Ghana prison system and highlighted by the Crime Check Foundation (2020).

1.3 RESEARCH OBJECTIVES

This research would attempt to grapple with the following key objectives:

- Investigate the underlying causes of over overcrowding in Ghana's prison system.
- Gather secondary data and study patterns and trends of crimes committed in Ghana over a certain period.
- Predict growth of prison population for timely intervention to avoid overcrowding.
- Establish how IoT intervention could be deployed in managing petty offences to address overcrowding in Ghana's prison system and review the feasibility of tracking petty offenders.
- Estimate potential cost-benefits analysis of the system when deployed.

1.4 IMPORTANCE OF THE STUDY

The proposed new concept of prison is to provide an innovative parallel prison management approach where the conventional brick and bar prison system would continuously serve critical offenses and a cost-effective miniature IoT Electronic Monitoring solution deployed in managing petty offenses. This study is very important and would impact various facets of our lives and contribute significantly to global, regional, and national reforms within the criminal justice delivery systems. Over the years, the government of Ghana periodically invests in the expansion of some prisons as cited in Ghana's Budget Statement (2015, p128) where the Ankaful prison was expanded to provide safe custody of prisoners to reduce overcrowding. This periodic intervention is unsustainable because the growth of the prison population far outstrips investment in infrastructure. With this intervention, the government can channel its resources into IoT Electronic Monitoring options which could be more cost-effective. The proposed option would also help reduce crime since it would strengthen the justice delivery process and promote the constitutional right of inmates by not subjecting them to a dehumanizing situation through overcrowding in prison. When breadwinners and vagrants are incarcerated using IoT EM alternatives for petty offenses, they can still work to service their fines and support their families. The potential to meet hardened criminals will reduce and by extension could reduce crimes. At the regional level where countries have signed various declarations such as the Ouagadougou declaration on Penal and Prison Reform in Africa (2002) where 123 delegates from 38 countries including 33 African countries met to deliberate on prison reforms focusing on addressing overcrowding and other challenges, Ghana with this new IoT Electronic Monitoring reforms would be better placed as a leader in the sub-region on prison reforms in Africa and as well contribute towards the attainment of Sustainable Development Goals 16. These are some of the key benefits of the proposed systems at various levels. The proposed solution is to help address the humanitarian challenges facing inmates in prison. Reduce crime where hardened criminals meet petty offenders and serve as models for global, regional, and national adoption in the fight against crimes.

1.5 SCOPE AND LIMITATION

The research is focused on providing prison reforms using IoT Electronic Monitoring technology solutions in managing petty offenses and addressing overcrowding challenges within the brick and bar prison. According to the Ghana Prison Service, the category of offenders under care are convicted (long and short), life, death row, pre-trial, and juvenile. The proposed IoT electronic Monitoring option would focus on petty offenders convicted, pre-trial, and juvenile groups. Even though various actors within the criminal justice system contribute directly or indirectly towards the incarceration of petty offenders leading to overcrowding, the buck stops with the prison administrators in finding a pragmatic solution to this global scourge. Therefore, the study would rather focus on the object of punishment (prison) which in some cases has been used disproportionately for retributive punishment. The study intends to empower prison administrators to deploy IoT Electronic Monitoring technology models to handle petty offenders within their ambit more efficaciously.

Some of the notable limitations of the study were data access and the lack of granularity in existing data sources. Also, there are concerns of privacy, ethics, and security gaps identified in deploying IoT EM technologies.

1.6 DISSERTATION STRUCTURE

This study is organized into five (5) Chapters.

Chapter One (1) deals with the introduction which contains the rationale, case study, research questions, and objectives, the importance of the study, scope, and limitations.

Chapter Two (2) provides the necessary literature review. It, therefore, reviews the historical and empirical literature related to the study. This includes an introduction, Origin of the use of prison, usage of techno correctional devices, IoT and other technology innovations in prison management, rate of recidivism, and geospatial impact of IoT and concludes with a summary.

Chapter Three (3) focuses on the methodology and methods adopted in the research. This includes an introduction, research philosophy and strategy, relevance and reliability of the study, questionnaire and data collection, data analysis and justification, ethics and biases, and the limitation to the study.

Chapter Four (4) discuss the analysis, discussions, and findings within the context of the research questions and objectives. This includes an introduction, the prisoner demographic, underlying causes of overcrowding, the potential impact of IoT EM deployment, cost-benefit analysis of the existing and proposed solutions, analysis of secondary data for trends and patterns on crimes, prison population growth models among others.

Chapter Five (5) highlights the recommendations and conclusions of the study

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter focuses on a review of literature on the concept of prison and various interventions deployed as part of efforts to address overcrowding challenges ingrained in the brick and bar prison system. It also highlights some of the challenges with previous intervention deployed to address prison overcrowding and proposed a pragmatic approach to addressing this issue comprehensively. The chapter further shared light on the genesis of Electronic Monitoring devices deployed for prison management, the rate of recidivism, and potential geospatial data benefit from IoT devices. It concludes with a summary of the chapter and **identified the gaps this study intends to address.**

2.2 ORIGIN OF PRISON SYSTEMS AND INTERVENTIONS TO ADDRESS OVERCROWDING

The history of imprisonment dates back centuries ago, where the purpose of confining a person within a prison was not to punish them but to detain the perpetrator for a crime temporarily until the actual punishment could be carried out (Crime Museum, ca.2017). However, in the 18th Century, a British philosopher named Jeremy Bentham developed a hypothetical prison termed panopticon where one guard concealed in the centre of prison inmates, controls the prisoners through his presume observation (Wood and Wood, 2010). Some of this innovation later evolved to the use of brick-and-bar prisons to detain offenders. This form of imprisonment has been in existence since the 19th century and adopted by most countries across the globe as a form of punishment for committing a crime.

Since its adoption, the brick and bar prison system has undergone several reforms to its current state even though most of these reforms varied across countries and localities. One of the key challenges necessitating many of the reforms was the burden of prison financing and overcrowding which has been acknowledged across the globe as arguably one of the single biggest challenges facing the prison system. **According to Penal Reform International (ca. 2020), about 124 countries** exceed their maximum occupancy rate with 23 of such prisons more than double their capacities. This statement points to the fact that even though countries have peculiar prison challenges, overcrowding was a global phenomenon. Some countries in their attempt to address overcrowding challenges, resorted to building new prisons which seem only effective within the short-term but failed in the long term. A study was undertaken by Reno et al (2000, P.2) revealed that construction and operationalization of new prisons are extremely expensive and constrain on budget makes this approach to resolving overcrowding issues in penal systems a failure and impractical.

Other jurisdictions sought to find ways to address the two main drivers of overcrowding in prison identified as admissions and length of confinement by instituting reforms within the entire criminal justice system. Most of these reforms focus on improving efficiency in the legal system where different actors interface at different decision points during the pre-trial and sentencing stages which turn out to be ad-hoc measures but ineffective in providing lasting solutions to prison overcrowding. A case in point is the Justice for All program (JFAP) which is a mobile in-prison

special court sitting as part of measures to decongest Ghana's prison population (PFO foundation, ca. 2020). Even though the program had helped reduce the inmate population by rescuing mostly remand prisoners, its effectiveness has diminished since most of the pre-trial detention cases have been resolved. However, the challenges of prison overcrowding in Ghana is far from over

2.3 USE OF 'TECHNO CORRECTIONAL' MEASURES

As part of an effort adopted by countries across the globe to provide a pragmatic solution to prison overcrowding; was the resort to the use of "techno correctional" options. Nellis (2015, p.8) defines "techno correctional" options as the application of technology to control and manage prison offenders. Countries in different parts of the world are resorting to the use of electronic monitoring devices as one of the most effective options to stem prison overcrowding challenges and reduce costly incarcerations of offenders. Decades of investment in electronic monitoring technologies are yielding some dividends in the management and administration of prison offenders. According to Reagan (2017), the history of the use of technology to track offenders' dates back to 1964 when Ralph Schwitzgel mooted that idea, which was subsequently implemented by the Department of Corrections in 1980. Since its introduction, there have been several innovative attempts to deploy similar or advanced technologies in the management of prison systems. Graham and Molvor (2017) identified three different types of electronic monitoring devices leveraging Radio Frequency (RF) tagging, Global Positioning System (GPS) tagging, and Remote Alcohol Monitoring (RAM). One could argue that RF and GPS tagging are the two main classical EM options and the RAM option being an upgrade or improvement in the supervisory deficiency of electronic monitoring devices.

One of the pioneer attempts in the use of Radio Frequency electronic monitoring technology to track prisoners according to Max (1993, p.34) was deployed in the US which involved an anklet transponder electronically linked to a telephone modem. This was one of the earliest attempts in the use of technology as an alternative to conventional brick-and-bar prison. The device was mainly used to impose restriction on offenders from getting access to certain exclusive zones and the attached electronic monitor trigger signal to a central station to sound alarm when the offender attempt to breach the restricted zone resulting in rearrest and imposition of a more severe sanction. However, this model of the alternative prison system of Electronic Monitoring was not cost-effective, and the technology used at the time was inefficient with limitations on effective offender tracking.

According to Belur et al (2020, p.2), the shift from Radio Frequency to more advanced Global Position Systems began in the 1990s which enhanced monitoring of offenders over longer distances. One of the pioneer GPS trackers according to Drake (2012) was produced by Pro-Tech monitoring Inc in 1997. The device was carried in a backpack like existing tracking devices in the market at the time. This device consisted of a cell phone, GPS receiver, and a battery all integrated into one box which made the device bulky and robust to operate. The system operates by

electronically teetering the box to the offender with a transmitter attached to the ankle. The gap identified with this form of EM was the chipset used is outmoded by today's standard and the tracker did not also add any layer of supervision of offenders beyond monitoring.

According to Wood (2010), a more advanced Electronic Monitoring tracker leveraging GPS and Radio Frequency option was the BI ExecuTrack AT for monitoring mostly prisoners on parole or probation. Even though this tracker was a better improvement of GPS tracking for prison inmates and helped cut the cost born by taxpayers on conventional prison systems through the effective implementation of prison without walls, the use of two-pager size black boxes per prisoner made the use of this device a bit cumbersome. It was embarrassing to strap the device around the ankle of prisoners in public places which is one of the downsides of this electronic monitoring option.

Recent use cases of Electronic Monitoring are focus on improving the supervision and monitoring of offenders in relation to specific offenses. Budinski and Berat (2019) in their study on the use cases of IoT, suggested how the technology could be deployed to turn dusty old prisons to complete IoT solutions. The study cantered largely on the value of IoT to provide complete automation of prison systems to become smart penitentiary facilities. Budinski and Berat (2019) suggested various ways IoT devices could be deployed to micromanage both prison staff and inmates uniquely to achieve the objective of a smart penitentiary facility. One of the merits of this approach is how the dataset generated can be uniquely traced to the source. The huge data generated by micromanaging prison systems and actors could serve as potential big data initiatives to study crime patterns.

Another comprehensive study on prison management was undertaken by Braun (2019) who acknowledge the potential of the Internet of Prison (IoP) to provide a smart prison solution. According to Braun (2019), IoP technology could be deployed in areas such as tracking offenders, face recognition, biometric trackers, ID badges, among others. This study highlighted extensively how IoP technology could be deployed to transition prison management like what has been proposed by Budinski and Berat (2019). One of the critical suggestions made by Braun (2019) is the need for external deployment of IoP for offender tracking to rather focus on petty offenses which is one of the key highlights of this study. The study of EM monitoring focusing on IoT is one of the innovative reforms this study seeks to explore.

Wood and Wood (2010, P.2) argues that GPS devices were increasingly becoming the preferred alternative to conventional incarceration as traditional prison was considered a failed system due to high numbers of incarcerations with its concomitant overcrowding challenges. According to Nellis (2015) who states that countries within the EU zone faced with prison overcrowding challenges resorted to the use of electronic monitoring devices to overcome these challenges. Since electronic monitoring had become pervasive as one of the most effective tools in prison management, these countries converge to adopt common standards and ethics in the use of these devices for the safe and effective administration of the prison system. One of the key highlights was the acknowledgment of the potential to explore **offender behavioural** patterns gained from a

large-scale aggregation of GPS data which remains a grey area in many jurisdictions. This is one of the key gaps this study intends to explore. Another critical downside identified with most GPS and RF electronic monitoring devices is their inability to deter crimes. Even though there are mechanisms to alert supervisory authorities of a breach, the offender could only be rearrested after reoffending. But this gap could potentially be addressed by leveraging data and the use of scalable IoT options. With emerging smart cities, IoT Electronic Monitoring options with sensors could be deployed to supervised specific offenses like the case of Remote Alcohol Monitoring. With a sensor, controller, and actuator effects of IoT devices, specific readers could be deployed at various locations to boost the supervisory role of IoT EM monitoring devices. Also, existing EM devices have challenges with batteries running down quickly which can be improved when deployed to communicate on NB-IoT as proposed in this study

2.4 IMPACT OF ELECTRONIC MONITORING ON RECIDIVISM

According to Brittingham and Brittingham (1984) reference by Li and Radke (2012) “crime is an antisocial behaviour and a phenomenon which is of great concern to human societies with the potential to cause ‘death, injury, fear, damage, and inconvenience’ as well as huge expenses and losses”. Generally, crimes whether petty or severe are associated with some negative consequence and this study does not seek to downplay the effect of crime in our societies but rather to ensure punitive measures are not disproportionate with the tendency to even amplify crimes. In this regard, the study also explores the rate of recidivism with the increasing use of Electronic Monitoring in most countries since the successful adoption of IoT EM can also be measured by the level of recidivism. According to Reagan (2017), the criminal justice community defines recidivism as criminal behaviour after being convicted, punished, rehabilitated, and released and the offender repeats offense or re-offends. The study in this area has mixed views with limited literature since the implementation of the technology is still growing. According to Graham and Molvor (2015) studies on the impact of EM on recidivism concluded with either modest, minimal, nonexistence or negative outcome according to (Razema, 2013) in contrast to other studies undertaken in continental Europe, Israel, and a large part of the US which shows a positive outcome. A study undertaken by Albrecht (2005) recorded 11% and 18% recidivism rates for Sweden and England/Wale respectively without comparative figures on recidivism on similar offenses prior to the implementation of electronic monitoring. Payne and Gainey (2004) cited by Bulow (2013) presented an empirical study supported by data where respondents were of the view that they do not intend to breach the conditions of their suspended sentence for Electronic Monitoring since that could worsen their plight. Therefore, the deterrence effect of imprisonment is not dismissed or irrelevant when one assesses the general deterrence effect of EM. Further studies in this area would justify the suspended sentence even though in this study, the focus on petty offences for the choice of IoT EM has minimal risk. Option for scalable IoT solutions may provide solutions for effective supervision of offenses as nations advance towards smart cities.

2.5 POTENTIAL IMPACT OF IOT EM MONITORING ON PREDICTIVE CRIME AND PREVENTION USING GEOSPATIAL DATA

According to Esri (2012), every offender, crime, or incident is somehow linked to a location or place that can be identified geographically and mapped. This feature of mapping crime they strongly believe could help inaccurate mapping and analysis of crime using different statistical analyses to explore neighbourhood crime correlation and other relationships with the objective to predict and prevent such crimes from happening within communities. Li and Radke (2012) in their study on how geospatial data could contribute to neighbourhood crime investigation cited the Profit targets theories where criminals tend to concentrate on locations where there exist more opportunities for them to obtain profits and victimize their targets. This argument further indicates how the reliance on geospatial data from IoT EM could help zone in on crime hotspots and possibly remove any incentives that invite specific forms of crimes at a certain hotspot. A study was undertaken by Chainey and Ratcliffe (2005) referenced by Royo et al (2020) defines a hotspot as an area of high crime concentration, relative to the distribution of crime across the whole region of interest. They further argue that studies of crime and place have identified that crime has “an inherent geographical quality. The arguments presented by different researchers regarding the strong correlation between crimes and location further justify the need to deploy more advance IoT electronic monitoring options to help improve prison management with the potential to generate geospatial data to control crimes. Even though one may argue that crime mapping is not new and has been used by the police in their approach to dealing with crimes, it only makes sense that strong collaboration with the prison administrators who are the custodians of offenders and as such the last stage of the data aggregation could improve the process significantly and produce more reliable data models. Even though the New York police department use of CompStat for predictive policing was heavily criticized as introducing racial biases as revealed by the study undertaken by Panelli (2018), the gap could be addressed with the potential to use big data and collaborate with prisons administrators which is one of the key focus of this study.

2.6 SUMMARY

From the literature explored, the most effective and modern strategy adopted in addressing prison overcrowding across the globe is the use of “techno correctional” devices. The deployment of this option for managing crimes is on the ascendancy. Particularly the use of GPS tracking devices for surveillance, restriction, and confinement of prisoners on parole, probation, or other forms of non-custodial sentence option. Advancement and improvement are ongoing to enhance IoT supervisory deficiency.

In the literature, the potential increase in recidivism was explored to help measure the effectiveness of the use of the IoT EM option. Some EM offender’s admissions of the deterrence effect of imprisonment not being dismissed or irrelevant when one assesses the general deterrence effect of EM strengthens the position of research to focus on the limited use of EM for petty offense at this stage.

In addition, even though some of the studies acknowledge the potential benefits to leverage on geospatial data to provide predictive and proactive forms of crime control and prevention, aggregation of location intelligence data remains a grey area in many jurisdictions, particularly in the field of social sciences. Therefore, this study would contribute to filling the gaps in some of these areas using IoT EM intervention for petty offenses.

3.0 METHODOLOGY AND METHOD

3.1 INTRODUCTION

This chapter focuses on the research philosophy, the research strategy, and data collection methods adopted to facilitate a comprehensive study of prison management challenges in Ghana. It also shared light on the relevant steps taking to obtain data from the Ghana Prison Service to get insight on the extent of prison overcrowding challenges and its impact on prison administration. The relevance and reliability of the techniques adopted in data collection and some of the ethical implications of the study and biases. The feedback in this section was to throw more light on the scientific processes and procedures that was pursued to arrive at logical data collection methods in line with the research objectives.

3.2 RESEARCH PHILOSOPHY

The philosophy underpinning this research is pragmatism. The main aim of pragmatism is to look at science and philosophy for the opportunities they afford us in finding meaning in our lives. According to Saunders and Tosey (2011), this philosophy considers the fact that there is no single viewpoint that can give an entire picture of a situation and that there may be multiple realities. In this case, we seek to rely on the IoT EM technology option to facilitate the imposition of non-custodial sentences for petty and generate data to explore different ways of tackling prison overcrowding using data from sensors and other sources like IoT Electronic monitoring devices.

One wondered why incarceration was used as punishment for petty offenses in Ghana even though the weight of such offenses were considered misdemeanours under the Criminal Offence Act 1960 (Act 29) and could be treated differently without necessarily incarcerating offenders. Therefore, the disproportionate use of incarceration compelled the need to explore the IoT EM option to provide a more pragmatic approach to managing petty offenses. This was especially important because some researchers had cited evidence to suggest that incarceration of petty offenders has the tendency to amplify crimes directly or indirectly for victims or their relatives.

Furthermore, the disproportionate use of the brick and bar prisons for almost all offenses has led to overcrowding which has serious ramifications on prisoners and prison administration. The worse impact of overcrowding in prisons is the potential to cause death and the possibility of petty offenders meeting hardened criminals who can influence them negatively.

3.2 RESEARCH STRATEGY

The research strategies adopted in this study were a mixed method involving case study, desktop research, and action research. The choice of these strategies was informed by the philosophical position considered in this study. According to Bhatta (2018) who states that philosophical position helps define the ontological and epistemological characteristics of research, it becomes fundamental in the choice of research design. Therefore, considering our choice of the research philosophy, the case study approach was adopted to elicit in-depth information on the extent and nature of overcrowding and other challenges persisting within the Ghana Prison Service for a more

scientific reform backed by data. The scientific approach to this problem backed potential data from IoT devices is very critical since several alternatives to prison overcrowding in the past without the option to explore big data insight were unsustainable. The collection of prisoner location information from petty offenders with time could provide data for a proactive approach to addressing crimes by drawing insights on crimes base on locations, economic indicators, and prisoner behavioural characteristics. The use of a case study served as a suitable research strategy in exploring the nuances of prison management challenges by engaging officers at the Ghana Prison Head Office and asking critical questions on phone to better understand the current challenges. According to Gerring (2007) reference in Bhatta (2018) who states that a case study is suitable for an intensive study of a single case where the purpose is to at least in parts shed light on a larger class of cases. This explained why we adopted this approach to study the challenges of overcrowding in the Ghana Prison Service and adopt best practices in addressing a similar situation in other overcrowded prisons. For a study that seeks to investigate the reality of prison overcrowding challenges in their natural environment, the use of a case study was very critical, focusing on in-depth information to serve as a useful starting point for multi-case study in the future. Even though some researchers such as Reno et al (2000) have argued that prison overcrowding is very much a localized problem and due consideration must be given to the context and locality of the crime, his argument holds when the entire criminal justice system is being considered. However, in this study, the focus is on reform to the brick and bar prison management and the challenge could be similar across several jurisdictions. Therefore, lessons learned in this study could be replicated in another jurisdiction.

Also, the use of action research, in this case, was necessary because we sought to provide practical IoT electronic monitoring solutions to prison management challenges, particularly overcrowding. According to Cohen and Manion (1994, p. 192) reference in Clark et al (2020) who described action research as a vital strategy for an on-the-spot procedure designed to deal with a concrete problem located in an immediate situation with the ultimate objective to bring about lasting benefits to the ongoing process rather than some future location. This approach was, therefore, adopted to explore the practicality of how IoT electronic monitoring options could be deployed in managing non-custodial sentences for petty offenses as part of measures towards addressing prison overcrowding challenges which is an ongoing phenomenon and persist in several jurisdictions.

3.3 RELIABILITY AND VALIDITY

The template used to collect data primarily focused on the research objectives. Therefore, consideration was given to questions that could help elicit the right response to the research questions focusing on factual reporting from the prisons. The primary source of data was secondary data sources gathered from the archive of the Ghana prison service and other sources. The questionnaire designed as a template was used to elicit relevant information in line with the objectives of the study. The data used was compiled on prisoners using the admission book, prison form 2 small and form 2 large based on the sentencing regimes. The Ghana Prison Service has an

established record collation unit at all its facilities to record and furnish the Head Office with relevant and reliable information on inmates.

Some of the questions asked through the interview were meant to elicit an appropriate response on whether all prison facilities were adequately prepared for the proposed solution. Other questions sought to identify and understand the challenges of prison management at specific locations for the proposed intervention. Focusing on specific facilities was to understand the nature of the problems and how the proposed solution could help impact their work. The feedback received from these facilities using the existing communication channel of the prisons was more reliable, relevant, easy to replicate for other cases, and faster for comprehensive analysis.

3.4 DATA SELECTION AND COLLECTION

The data used in this study was largely obtained from secondary data sources based on a template questionnaire attached as appendix I, a list of offenses attached as appendix II, annual reports of the Ghana Prison Service, review of legal instruments, and other desktop research on petty offense classifications in Ghana. Following the establishment of contact with the Director-General of the Ghana Prison Service, the IT unit of the service at the Head Office in charge of coordinating activities of all the other prisons across the regions was advised to make available all relevant information to facilitate the study. Therefore, the office served as a vital resource in the provision of data and coordination of activities of other prisons in Ghana. Some of the critical information gathered from the IT service desk included their annual reports, power points presentations, legal instruments backing their operations, and other key web resources. The annual report obtained from the Head Office highlighted key achievements and challenges bothering the operations of the Ghana Prison Service and the data were compiled using their existing record offices from the regions to the Head office. The information according to the Ghana Prison Service comes from the Gate Journal which is the point of record of information of a prisoner at the point of entry to the facility. Other information which found its way into the annual report comes from the admission book and forms 2 which are used to record prisoner characteristics and sentencing regime. Therefore, the information in the annual report gave insight into how the database of the Ghana Prison Service was structured which helped in the design of the template questionnaire. Other documents shared revealed the nature of reporting from the regions to the Head Office based on the established communication protocol. Based on this understanding, relevant information was extracted as secondary data from the report and other information that was unavailable was requested using a template in the form of a questionnaire attached as appendix II.

The template was used to elicit relevant information such as prison types and risk level, nature, and underlying causes of overcrowding, available holding capacity and a current number of prisoners, basic cost implications of housing inmates, percentage of petty offenses, and suitability of IoT EM deployment among other critical questions. This option of collecting data was fast, reliable, and can easily be replicated for the multi-case study of prisons to address overcrowding

and other prison challenges with ease. The use of this option was mainly to have a consistent approach and feedback from all the prison facilities in line with the research objectives. This option was more efficacious leveraging existing data collection channels and established communication protocols from record officers in different prisons to the Head Office. Other granular information such as the classification of petty offenses that were not immediately available were extracted from the study undertaken by CHRI (2018, p.30-32) on petty offense in Ghana, focusing on chapter 7, 8, and 9 on misdemeanours in Ghana Criminal Code Act 1960 (Act 29). The information on petty offenses from CHRI was used to create a new column as a category of offenses in the dataset of offenses obtained from the Ghana Prison Service

The study further explored insight on potential IoT EM devices in detail to provide alternative sentencing options for petty offenses. This took into consideration existing EM options and identified gaps that could be addressed for the ideal IoT solutions. Efforts were made to explore how unique IoT EM devices could be developed at a highly affordable cost with the option for scalability for mass deployment. Therefore, the review of the cost of deployment of the proposed IoT device was considered and insight was drawn from the cost of similar tracking devices manufactured by Mantrac Company as part of an effort to obtain data to evaluate the cost-benefit analysis of the proposed solution. Other information obtains online on the cost of cloud deployment services, data cost, and application cost estimates were all considered juxtaposing it with the cost incurred holding petty offenders in prisons. The information was put together to give an ideal estimate of the cost implication of the IoT options proposed against the use of brick and bar prisons.

3.5 DATA PROCESSING AND ANALYSIS

The secondary data used in the analysis include the 2021 template received from Ghana Prison Service (GPS) attached as appendix I, 2018 offenses dataset obtained from GPS attached as appendix II. Sample prisoner data obtain from Kaggle attached as appendix III for demonstration of relationships between prisoner demographics characteristics and certain crime. Tables extracted from annual reports 2018 from Ghana Prison Service and the list of petty offenses extracted from 2018 CHRI report, the criminal offenses act (29), and geospatial data extracted from google cloud public dataset and merged with list of offences dataset received from GPS for demonstration between crime and geospatial data. All these datasets were captured on a spreadsheet and cleaned. The total aggregates were compared to reduce the level of inconsistencies in the total numbers obtained. The total number of inmates obtain from the template was 13480, the list of offences received had 44 different offences and the data extracted from Kaggle had 356 total number of records. Having reconciled the figures, the data was formatted, and columns were renamed to remove spaces before importing the data into Power BI for series of DAX transformations and analysis before visualization.

Also, the list of crimes received was merged with the aggregate geospatial sample data to demonstrate how offenses could be potentially mapped with GIS coordinates which has the potential for predictive crime solution based on location intelligence.

The data on cost implication was analysed in excel mainly due to the several assumptions (Average EM device cost, cost of cloud service, data cost, offender monitoring solutions among others) considered in arriving at the estimates. This was to help give a comprehensive insight on the cost implication of the proposed solution vis-a-vis the cost of holding extra inmates in prison. One critical consideration in estimating the cost was to focus on computation of only prison facilities where the number of inmates exceeded the available prison capacity since the study was not to eliminate prison systems but to address overcrowding and disproportionate use of prison for petty offences. The basic expenditure on inmates (food, toiletries, water, utilities, sanitation, uniforms among others) was obtained from the template and the personnel emolument cost of GPS extracted from Government of Ghana 2018 payroll data.

The last set of analysis focused on importing secondary data attached as appendix III obtain from Kaggle sources into google collab to demonstrate how extensive details on prisoner data could be used to explore insights, patterns, or correlation of offences for a more insightful and informed decision on crimes.

All these secondary data sources were used to conduct comprehensive analysis to generate insight in line with the objectives of the study. The choice of Power BI was to obtain a comprehensive granular detailed analysis, google collab for the study of patten or relationships between data, excels to facilitate data cleaning and reconciliation of aggregates.

Table 3. 1: Summary of Data Sources

Data type	Year produced	Attachment Index
Ghana Prison Service Annual Report	2018	Referenced
Aggregate Template prisoner dataset and offences	2021	Appendix I
Classification of petty offences from GPS	2018	Appendix II
Jail Booking sample data from Kaggle		Appendix III

Source: Author

3.6 ETHICS AND BIAS

The issues of research ethics were not taken lightly in view of the research settings. Therefore, one of the critical factors that premise data gathering was the need for all key stakeholders and participants to consent to participate in the research at their own will. All materials especially the data collection instruments were routed through the Head office for scrutiny by the Director-

General or his assistance for approval to be granted. The template was carefully designed and developed to help capture only relevant data for the study without infringing on inmates' privacy. Also, growing concerns regarding the Ethical implications of the use of Electronic Monitoring devices in tracking prisoners were considered. **Research conducted by Burow (2014)** cited by Bartels and Martinovic (2017) identified six key concerns regarding ethical implications of the use of EM. Some of the notable concerns are public risks and risks to the offender; the challenges of a profit-driven industry; loss of privacy; the risk of stigmatization; whether EM is a cause for unfairness; and reconciling EM with the aim(s) of punishment. Even though these concerns are germane and require serious attention, in this study, some of these concerns were addressed. For instance, on the issue of public risk, the proposed category of offenders to be considered is petty offenders and therefore poses very minimal risk to the public. Also, the use of IoT miniature bracelets unlike the anklet would be hard to notice and has the potential to reduce public stigmatization. The partial loss of privacy (location privacy) under the IoT electronic monitoring option far outweighs the total loss of liberty in prisons where prisoners are totally catered for and denied their liberty to work and fend for themselves and their families. The proposed IoT Electronic Monitoring option would allow petty offenders the desire freedom to move freely to conduct their business while under periodic monitoring and supervision. The use of the device would strictly focus on the petty offender's location privacy and biodata without breaching any other privacy of the petty offender. Another critical ethical consideration is the flexibility of the proposed wristlets IoT tracker to avoid embarrassment.

3.7 LIMITATIONS

One of the key limitations identified in this study is the use of a single-case study approach. This according to Yern (2014) reference in Bartha (2018) is considered weak because it only focuses on one institution and cannot, therefore, be generalized as global solution to prison management. Even though Yern's argument is relevant, the use of a unicas case study in this situation was vital for an in-depth understanding of a specific segment of the criminal justice system in charge of the object for punishment. Focusing on prisons in one country narrowed the problem to help propose a more pragmatic and sustainable solution to prison overcrowding challenges. Unicas at this stage like many other initiatives that became a success started small with the possibility to scale based on outcomes or results of a pilot study. It would not be logical to initiate the study by considering multiple prisons which may be costly with uncertainty in outcomes. Also, the use of templates in gathering data could be adopted and enhance as a standard reporting template for multi-case studies with ease and consistency. Multiple case studies may have to be considered for the proposed solution to be more acceptable as a global solution to prison management. Other limitations to this study were the unavailability of data at the granular level appropriate for categorization, overlaps in the definition of petty offense in the Ghana Criminal Code Act 1960 Act (29), and the lack of a variable in the Ghana Prison Service database to filter data based on only petty offenders in detention. Several assumptions were made in relation to cost implications and varying data received with different time periods. Resource limitation and the Corona pandemic also made it difficult to visit most of the prisons physically for first-hand information to examine the nature of

overcrowding and gather some primary data. Also, the location data on crimes used in this study may have some overlaps due to prisoner transfer to other regions. However, the impact on analysis was minimal as this group is in the minority. The varying period of data received could also affect the reliability of the figures for the period under consideration.

Draft

4.0 RESULTS AND DISCUSSION

4.1 INTRODUCTION

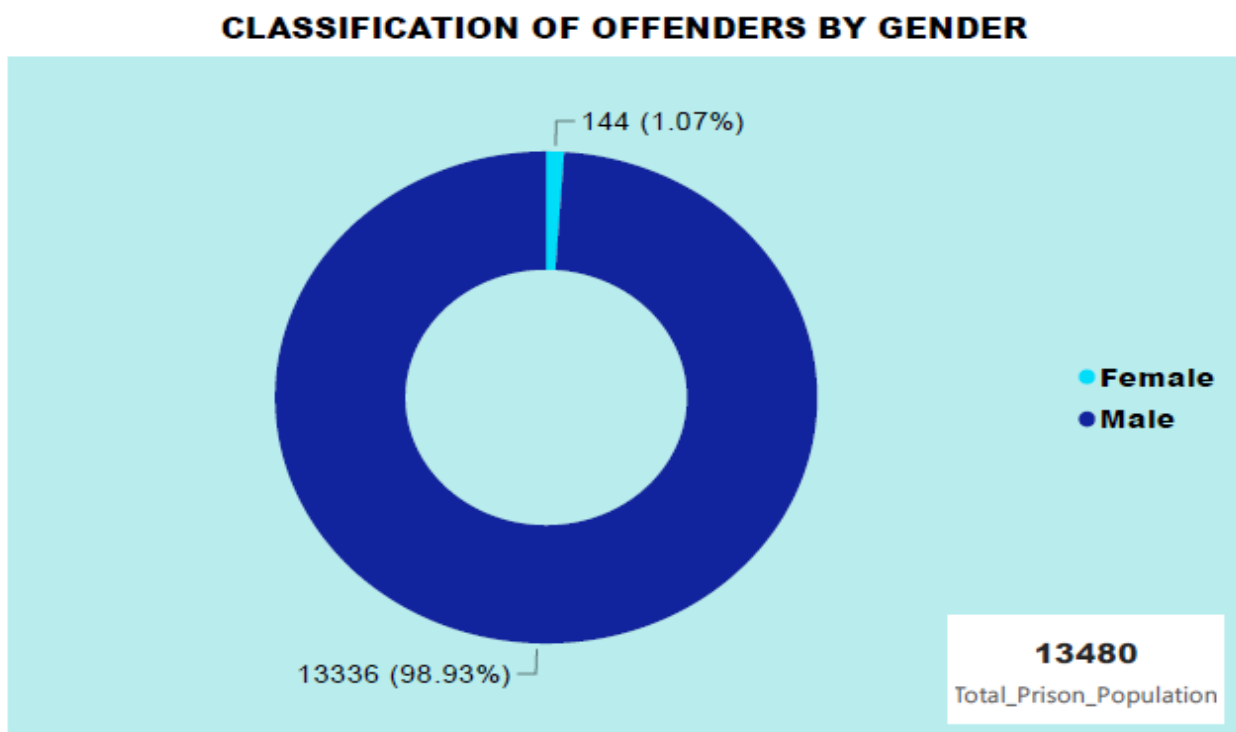
The analysis in this section relied on secondary data sources received from the Ghana Prison Service and other key online sources which were clean and processed in Power BI Desktop, Excel, and Google Collab to generate insights and graphs to inform discussions in line with the research objectives. The findings explored the demographic of the prison population to understand the characteristics of the inmates, prison types and then focus on the key objectives of the study.

4.2 INMATES DEMOGRAPHICS AND PRISON TYPES

Demographic of inmates by Gender

The donut chart in Figure 4.1 immediately highlights the number of males and females incarcerated by the Ghana Prison Service. The number of males prisoners was estimated as 13336 representing 98.93% of the total prison population while the number of female prisoners was only 144 representing 1.07% of the total prison population. The prison is largely dominated by males which should be of concern to key stakeholders since they are mostly the breadwinners in families and engage in a lot of outdoor activities.

Figure 4 1: Prison Population by Gender

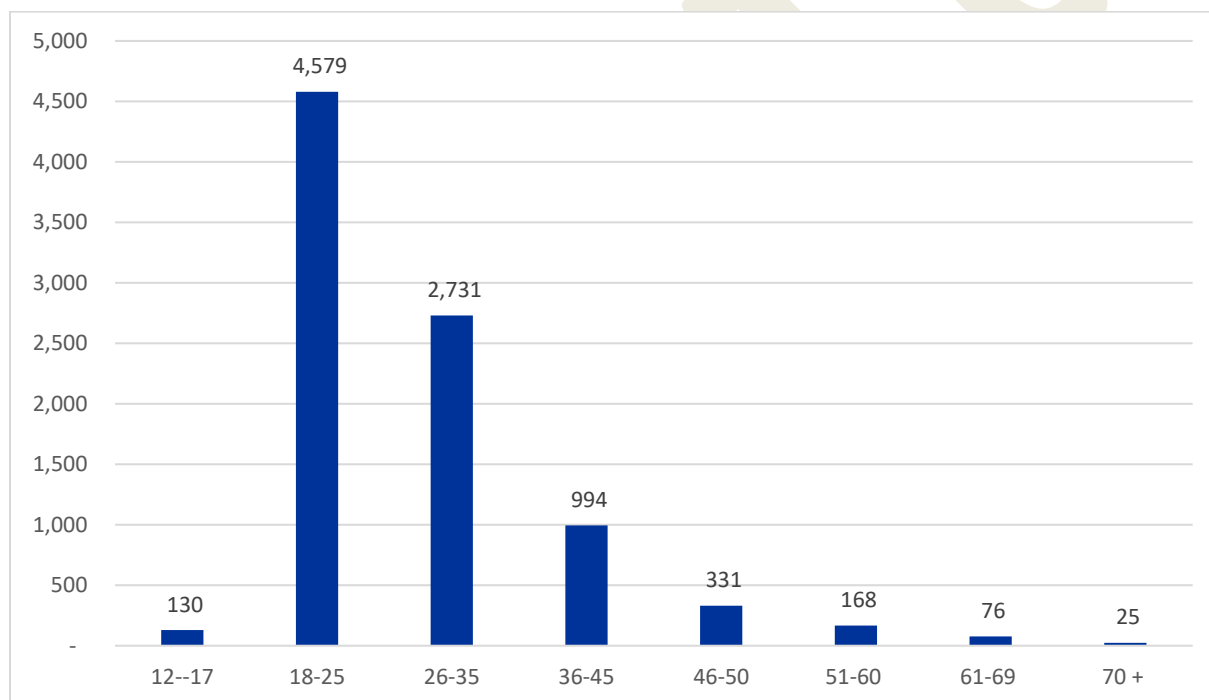


Source: Author

Age Distribution of Prisoners

The bar chart in Figure 4.2 gives detailed insight about the age group of offenders. The age group between 18-25 years constitute the highest number of inmates, followed by the group between 26-35 and then 36-45 with the least being inmates over 70+ years. The youth who are between the ages of (18-25) constitute more than half (51%) of the total prison population. Followed by the adult group (26-35) constituting a little above a quarter (30%) of the total prison population and those between the age (36-45) constitute about a 10th (11%) of the total prison population. The large proportion of the younger generation held behind bars is disturbing especially if their offenses are petty. These huge numbers of the younger populations who are the active working population of the country have their potentials being wasted behind bars for various degrees of offenses and the use of IoT EM device to salvage petty offenders could liberate these groups to be more resourceful to societies.

Figure 4 2 Different age groups behind bar in Ghana.



Source: Author

Nature, Types, and risk classification of Prisons

Since the problem of prison overcrowding was largely a space problem, the data collected using the template focused on understanding all the prison types and extent of overcrowding if any, and the underlying causes. The study identified 8 different types of prisons categorized by their level of risk in Table 4.1. The risk category helps in the classification of prisoners in the right facility.

Table 4 1: The number, types, and risk classification of Prisoners in Ghana

Types of Prison	Frequency	Classification
Senior Correctional Center	1	Low risk
Central Prison	7	High Risk
Local Prisons	15	Moderate to low risk
Female Prisons	7	Moderate to low risk
Open Camp Prisons	3	Minimum Risk
Agricultural Settlement	9	Minimum Risk
Medium Security Prison Nsawam	1	High Risk
Maximum Security Prison Ankaful	1	Very High Risk

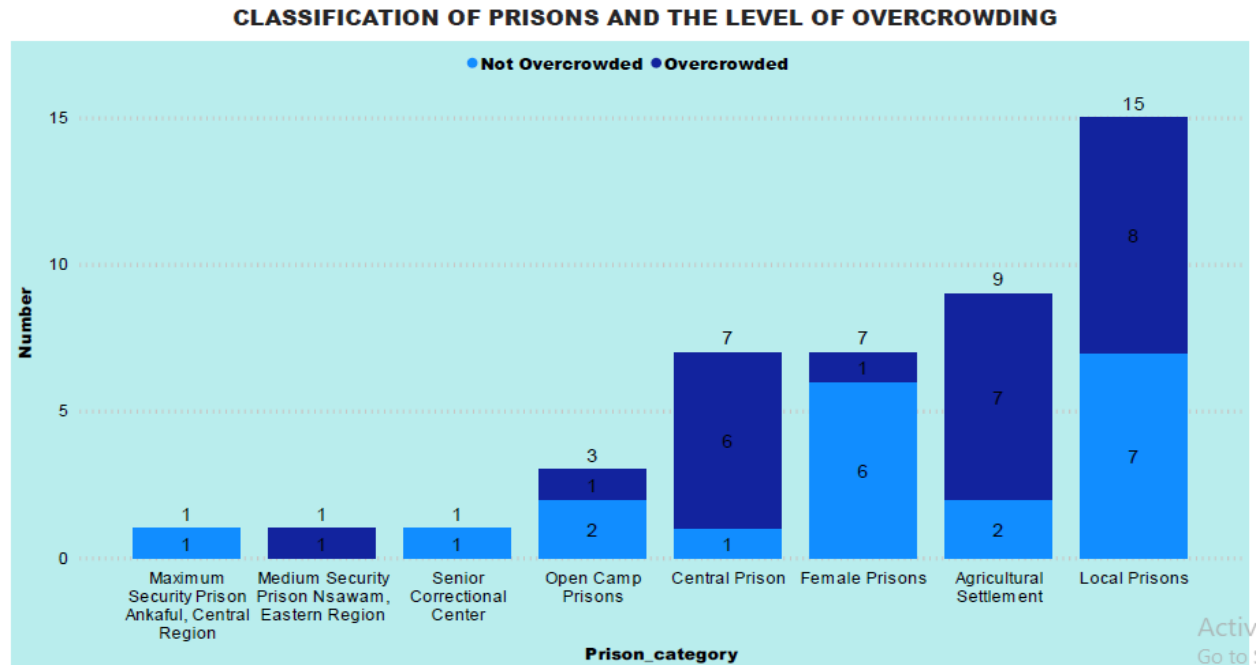
Source: Ghana Prison Service, 2018

Prison classification and level of overcrowding

The chart in Figure 4.3 highlights all the prison types in Ghana with emphasis on whether they are overcrowded or not which is one of the major problems faced by prisons across the globe. In all, there are 15 types of local prisons with 8 experiencing overcrowding, followed by 9 types of Agricultural settlement model prisons with 7 experiencing overcrowding, followed by 7 female prisons with only 1 experiencing overcrowding in that order.

Figure 4.3 gives a more detailed overview of the level of overcrowding across different categories of prisons in the country. The level of overcrowding for some specific prison categories such as the agricultural settlement, medium security and central prison is quite alarming and urgent measures are needed to depopulate such prison categories. With overcrowded prisons, offender classification becomes a problem where petty offenders are forced to intermingle with hardened criminals and get influence negatively.

Figure 4 3 Prison classification and the level of overcrowding.



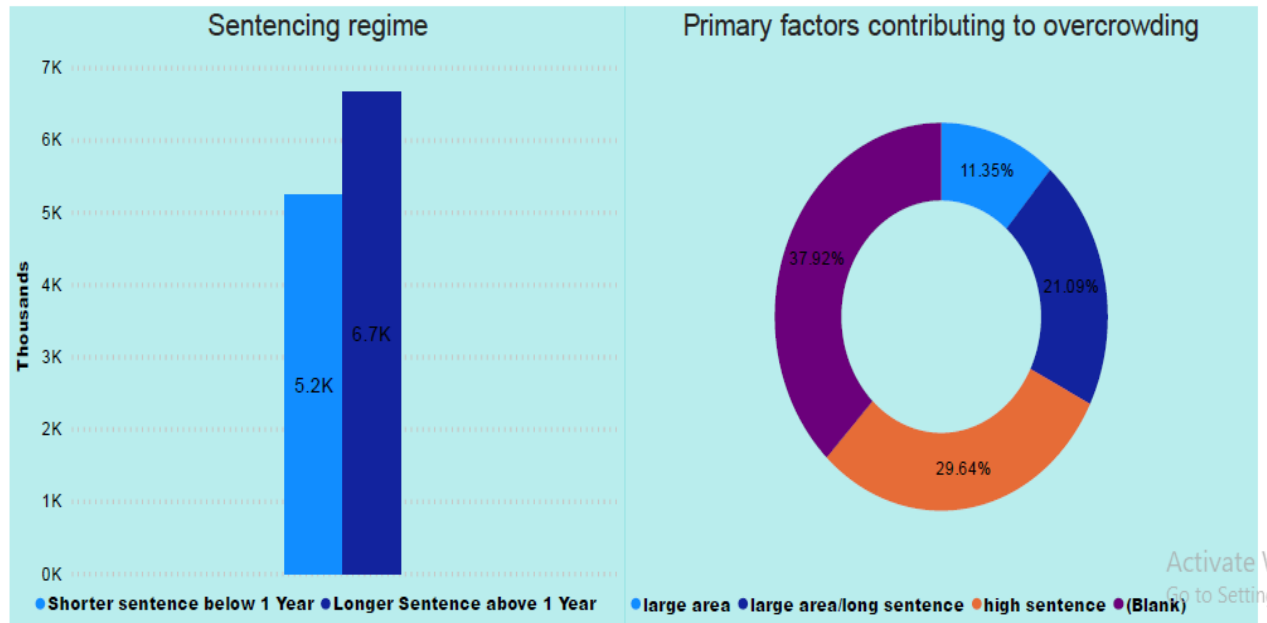
Source: Author

4.2 INVESTIGATE THE UNDERLYING CAUSES OF OVERCROWDING

The major highlight in this section is the identification of the key factors contributing to prison overcrowding. The pie chart in figure 4.5 shows the primary factors contributing to prison overcrowding. From the figure, **high sentencing** regime (above 1 year) imposed on offender's accounts for 29.64% of total inmates in prison, followed by **large area/ long sentencing** with 21.09% and **large area (prison serving larger communities)** constitute 11.3% which is the lowest. Overcrowded prison with no reasons assigned and few non overcrowded prisons put together constitute 37.92%.

To understand the nature and impact of the sentencing regime; particularly longer sentence (above 1 year) and shorter sentence (equal or below a year), the histogram in Figure 4.5 highlights the sentencing regimes. In all, 6.7K prisoners were jailed above 1 year and those serving below 1 year were 5.2K. It is obvious that the sentencing regime which defines the prisoner turnover for admission and exit has more prisoners serving longer sentences (6.7K) which stakeholders have identified as one of the key factors contributing to overcrowding. The implementation of the IoT EM option could potentially help assuage the impact on overcrowding by facilitating non-custodial sentencing for petty offenses.

Figure 4 Underlying Reasons Causing Overcrowding

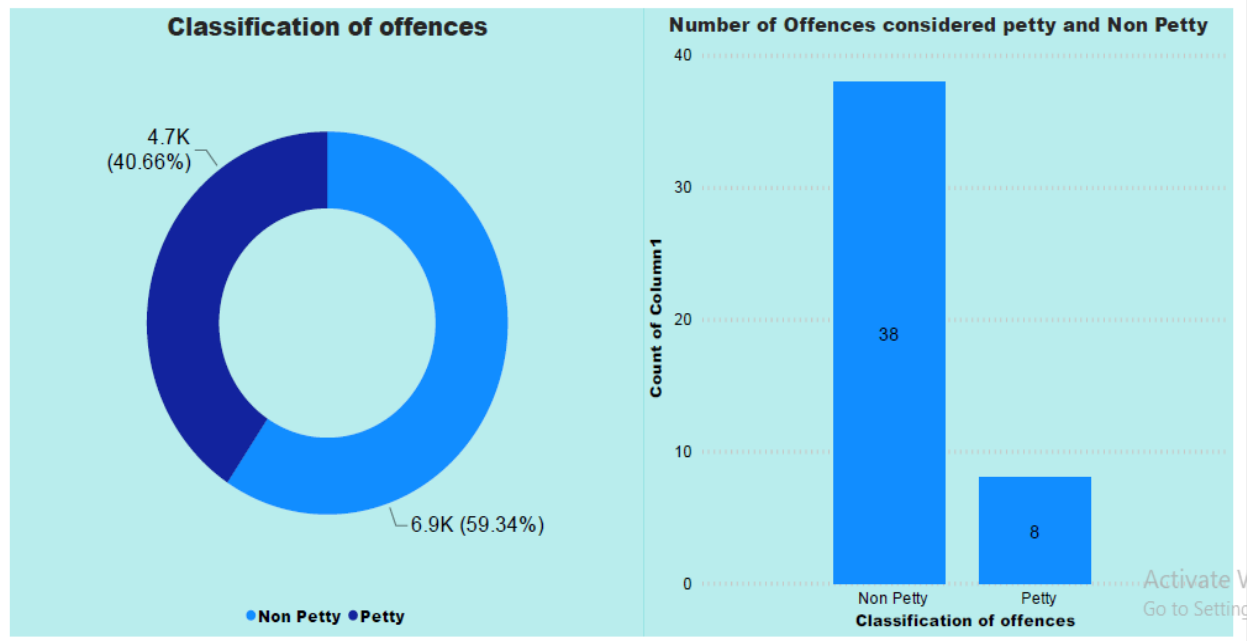


Source: Author

Overcrowding due to classification of offences

One of the key factors attributed to prison overcrowding was the incarceration of petty offenders. Using the Ghana Criminal Code Act 1960 (Act, 29), some offenses were reclassified as petty and categorised. From the pie chart in figure 9, it can be observed that petty offenders constitute 4700 based on a reclassification of offenses representing 40.6% of the total prison population whilst non-petty offenders constitute 6900 representing 59.3% of the total prison population. The bar chart shows the number of offenses that were reclassified as petty (8) and non-petty (38). Even though only 8 offenses were reclassified as petty offenses, the potential impact on the number of prisoners is so significant representing 40.6% of the total prison population. This clearly shows how impactful the proposed prison reforms could change the dynamics of prison overcrowding and address disproportionate use of prison. The detailed classification of offenses table is attached as appendix II.

Figure 4.5 Classification of Offences (Petty and Non-Petty Offences)



Source: Author

Level of overcrowding across different prisons and underlying causes

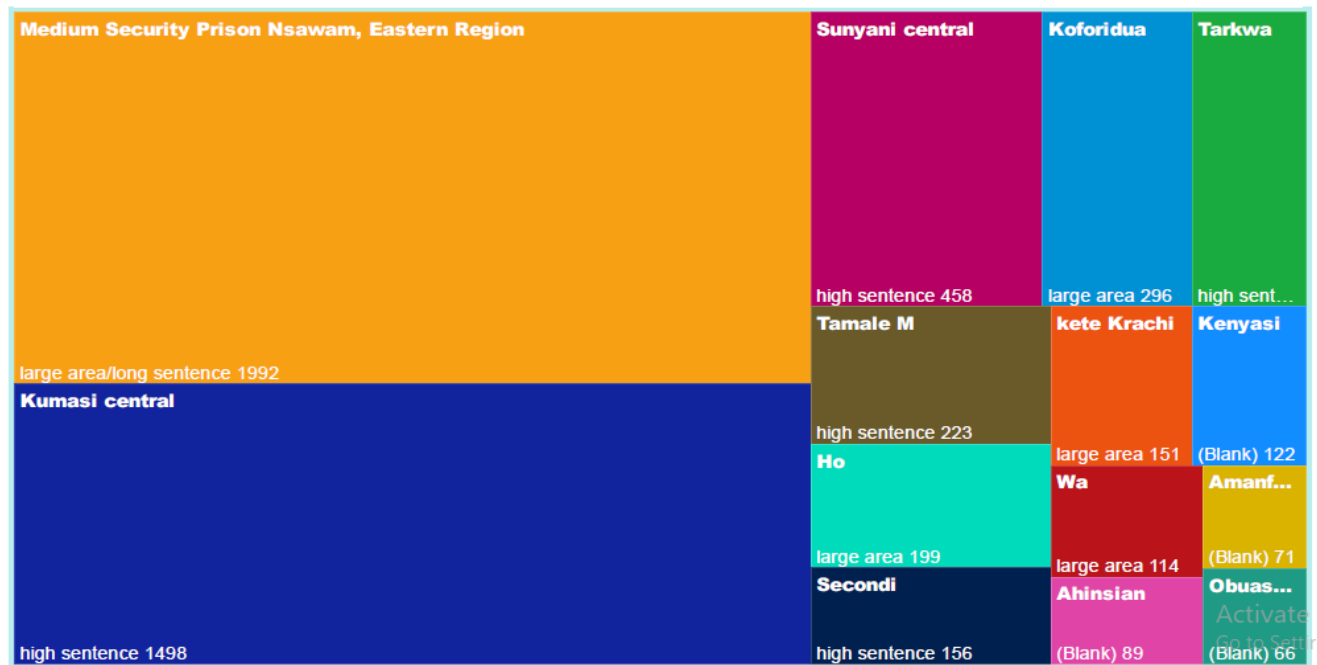
The map in figure 4.6 presents the details of some factors causing prison overcrowding at specific facilities. From the heat map, the size of the coloured rectangle depicts the facility with the highest level of overcrowding shrinking in that order to the least overcrowded facility.

The figure shows the pattern of overcrowding in various prisons spread across the country. The size of the situation is highlighted by the colour choices and the number showing the level and the extent of overcrowding across all the prisons in Ghana. The pattern can help informed policy on the urgency of overcrowding across different geographical areas.

From the heat map in Fig 4.6, the underlying factors causing overcrowding in Medium Security Prison Nsawam was attributed to it being used to serve large catchment area and also the imposition of long sentencing regime for some of the inmates resulting in overcrowding by 1992 more prisoners than the available capacity. This is followed by Kumasi with 1498 more prisoners than available capacity, followed by Tamale with 233 in that order to the least.

Figure 4.6 Overview of prison overcrowding in specific facilities and underlying causes.

UNDERLYING CAUSES AND LEVEL OF OVERCROWDING IN SOME PRISON



Source: Author

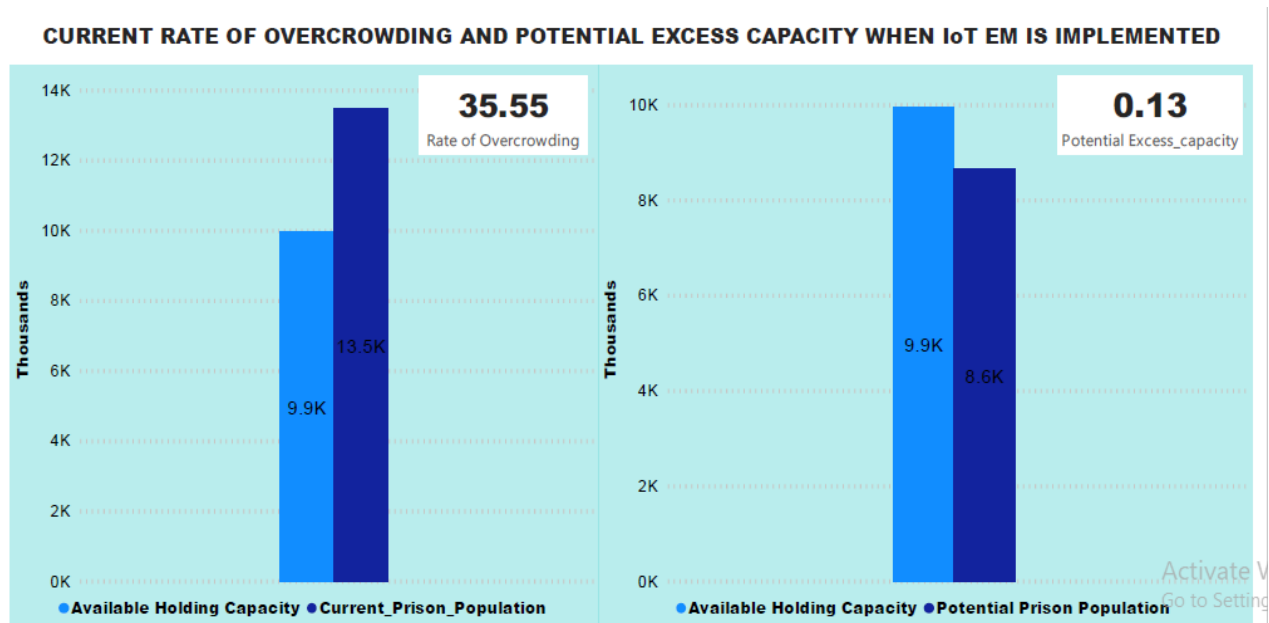
Potential impact of the proposed IoT on prison overcrowding

The bar chart in figure 4.8 highlights the total available prison capacity (9.9K) for **all prisons put together juxtapose** with the current prisoner population (13.5K) for all prisons put together. The percentage of overcrowding base on available and current prisoner population is 35.55%.

Out of the current prisoner population of 13.5K, the data revealed that 4.8K of the prisoners could be considered as petty offenders based on estimates provided the Ghana Prison Service. This figure is very close to the total obtained in figure 4.7 (4.7K) using offence reclassification.

When the proposed IoT is deployed to manage the 4.8K petty offenders identified by the Ghana Prison Service, the potential impact of overcrowding would significantly reduce, such that the prison would have an excess capacity of 0.13% as shown in Figure 4.8. In effect, there would be more available holding capacity to cater for hardened criminals and the current prison population would shrink from 13.5K to 8.6K.

Figure 4 7 Potential Impact of IoT EM intervention on overcrowding



Source: Author

4.3 PATTERNS AND TRENDS OF CRIMES ACROSS REGIONS IN GHANA OVER TIME.

Table 4.2 shows the aggregate of crimes across various location/regions in Ghana. At a glance, the region with the highest number of offences is Kofidua in the Eastern Region, followed by Kumasi in the ashanti region and other regions in that order. In all, the capital city (Accra) recorded the least number of offences (188) in 2018 as captured in Table 4.3.

Table 4 2: Crimes rate across regions

REGIONS IN GHANA	OFFENCES IN 2018
KOFORIDUA	3641
KUMASI	2419
TAKORADI	1209
CAPE COAST	1181
SUNYANI	1089
HO	954
BOLGATANGA	412
TAMALE	288
WA	268

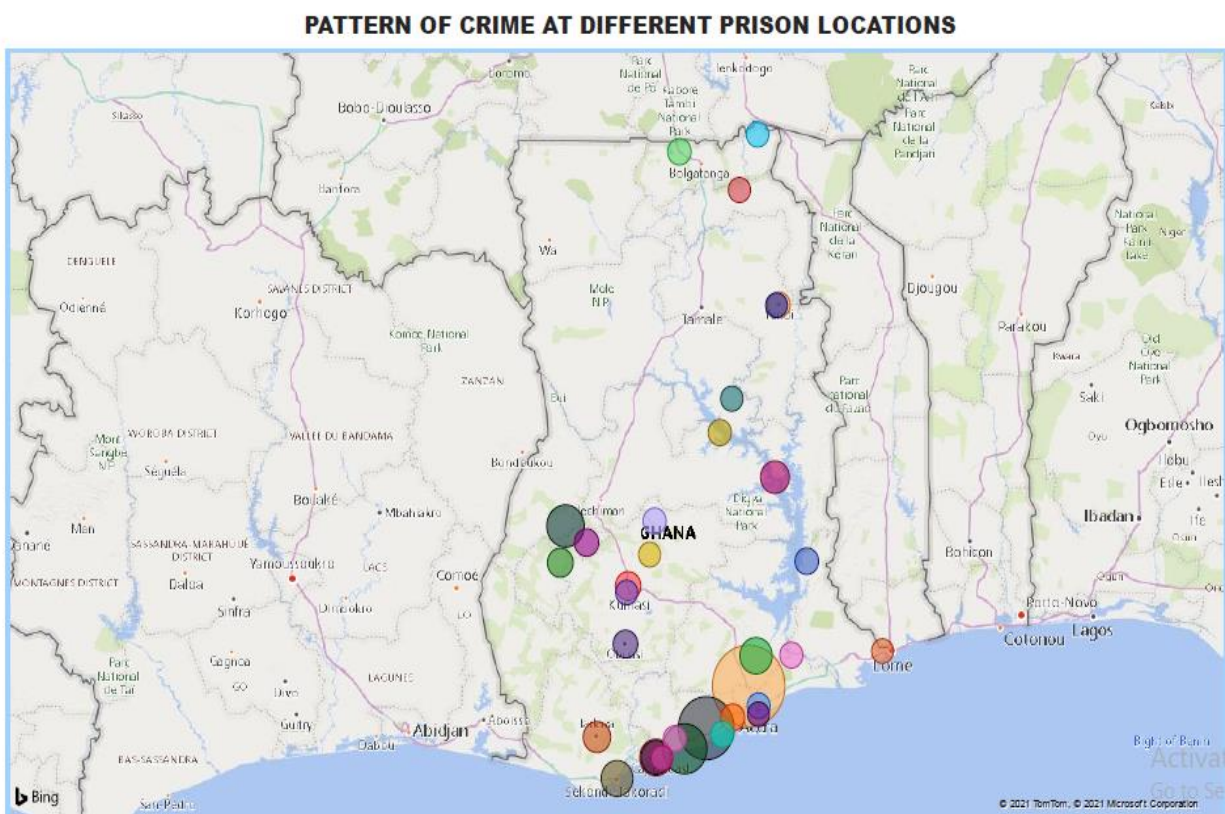
Source: Ghana Prison Service, 2018

PATTERN OF CRIMES ACROSS REGIONS USING BUBBLES

The visual map of Ghana in figure 4.9 displays bubbles depicting the varying sizes of crime to reflect the magnitude of offenses across different locations in Ghana. Most of the crimes were committed within the same region with few exceptions involving inmate transfer to other prisons at a different location. The essence of the chart is to provide visual insight into crime with bubbles showing the magnitude of offenses across different locations. The map showcases which locations in Ghana is prone to frequency crime.

From Figure 4.9, the southern sector has larger bubbles indicating high crime rate at certain geographical location. Key stakeholders can easily spot crime hotspots using this map as shown in figure 8. This visual display of bubbles showing crime by location could prick the conscience of key stakeholders to give specific attention to certain crimes prone areas.

Figure 4 8 Bubble chart overview of pattern of **crimes across regions in Ghana**



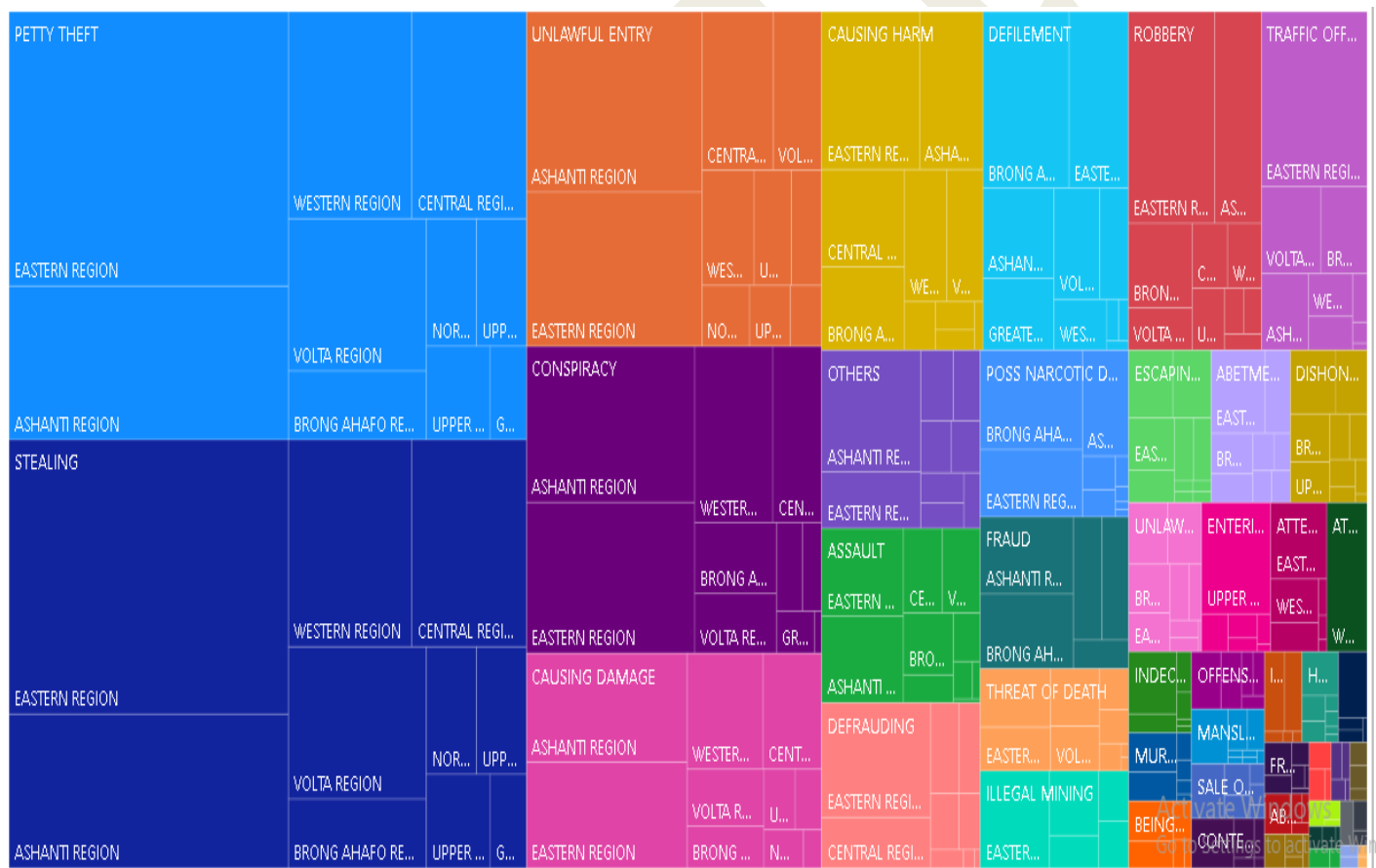
Source: Author

Patten of offences across different regions using heat maps in Ghana

The tree map in figure 4.10 gives a vivid insight into the types of crimes and highlights the intensity of specific crimes spread at different locations (Regions) in Ghana. The coloured rectangles display the magnitude of certain offenses spread across various regions. With the insights from the maps, petty theft constitutes one of the highest offenses recorded, followed by stealing (non-Petty), unlawful entry, conspiracy in that sequence to the least offense.

With this insight, it is easy to identify immediately which offenses occur frequently at a particular location. For instance, in Figure 4.10, petty theft was very high in the Eastern Region, followed by the Ashanti Region, the Western Region in that order to the least. This same pattern is highlighted by different colours across all the rectangles on the maps. This insight can assist policymakers have a well-targeted approach to addressing specific crimes base on location data.

Figure 4 9 Heat Map of all offences across regions in Ghana



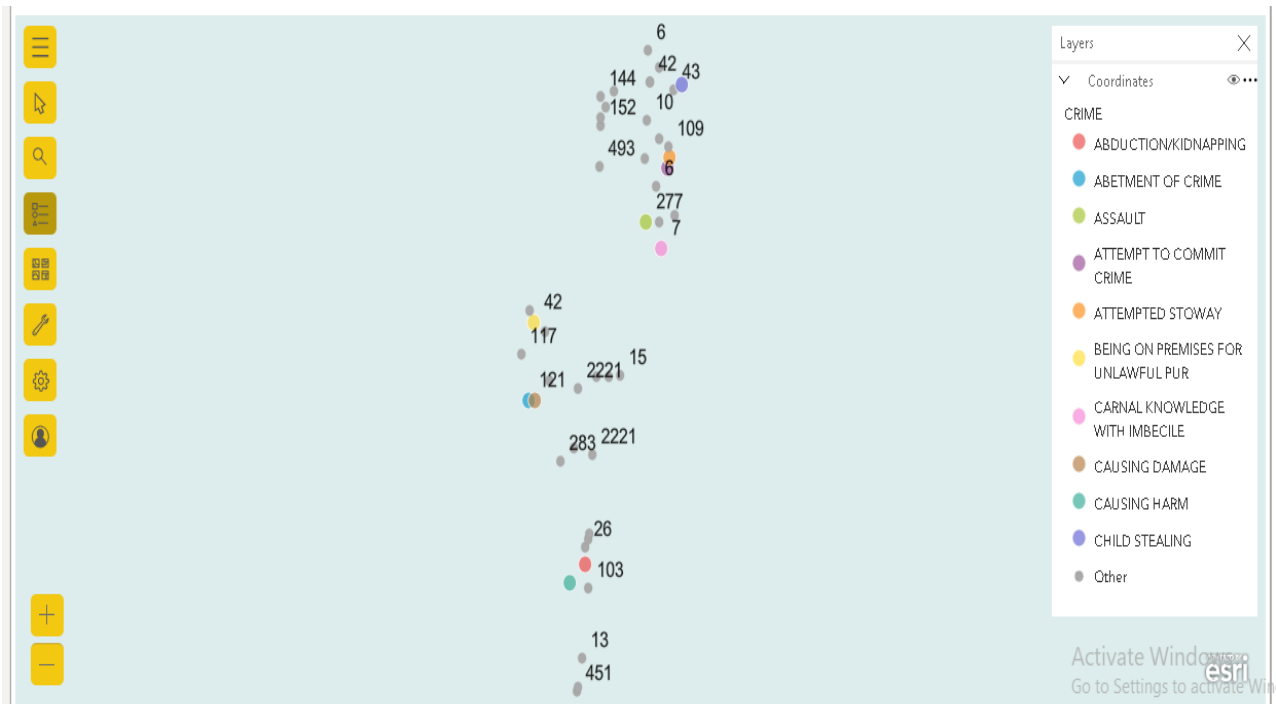
Source: Author

Geospatial data pattern of offences for potential improvement in location analysis of crime location.

Figure 4.11 demonstrates the possible or potential improvement in crime reporting and monitoring based on location intelligence (A much improved targeted location analysis than figure 4.10 above). The map shows the frequency of crimes across different locations by GPS coordinates and the legends depict the specific type of offense codified on the map. The dataset used in this demonstration was the list of the offenses received from the Ghana Prison Service and GPS coordinates extracted from Google Public Cloud dataset. This map is to demonstrate a strong correlation between crime and location for better inform policies to help predict and prevent crimes using various statistical models espoused using **where science of data**. Reporting crimes hotspot with the heat maps is too broad and does not really narrow it down for accurate crime hotspot analysis. The aggregated function produced in Figure 4.11 can be achieved using Google Big Query ST_ function shared on this link https://cloud.google.com/bigquery/docs/reference/standard-sql/geography_functions.

Esri argues that for crime to take place there must be a motivated offender, suitable target at a particular location. The intersection of the offender and suitable target at a **specific location** opens an opportunity for scientific analysis of crime focusing on these variables. The advances in location intelligence crime analysis could give a more comprehensive and insightful answers on the where, when, why, and how a particular crime. For instance, in Figure 4.11, **abduction/kidnapping** is codified as red spot on the map with 103 frequencies of occurrence at that spot. This mode of crime reporting focuses more on crimes on specific axes of the earth (latitude and longitude). Therefore, the map in Figure 4.11 is the projection of crimes and frequency of their occurrence at specific coordinates. The legend highlights specific crimes by colour and the frequency of occurrence of those crime as coded on the map.

Figure 4 10 Overview of offences across different geospatial coordinates (By latitude, longitude, and Crime Frequency)



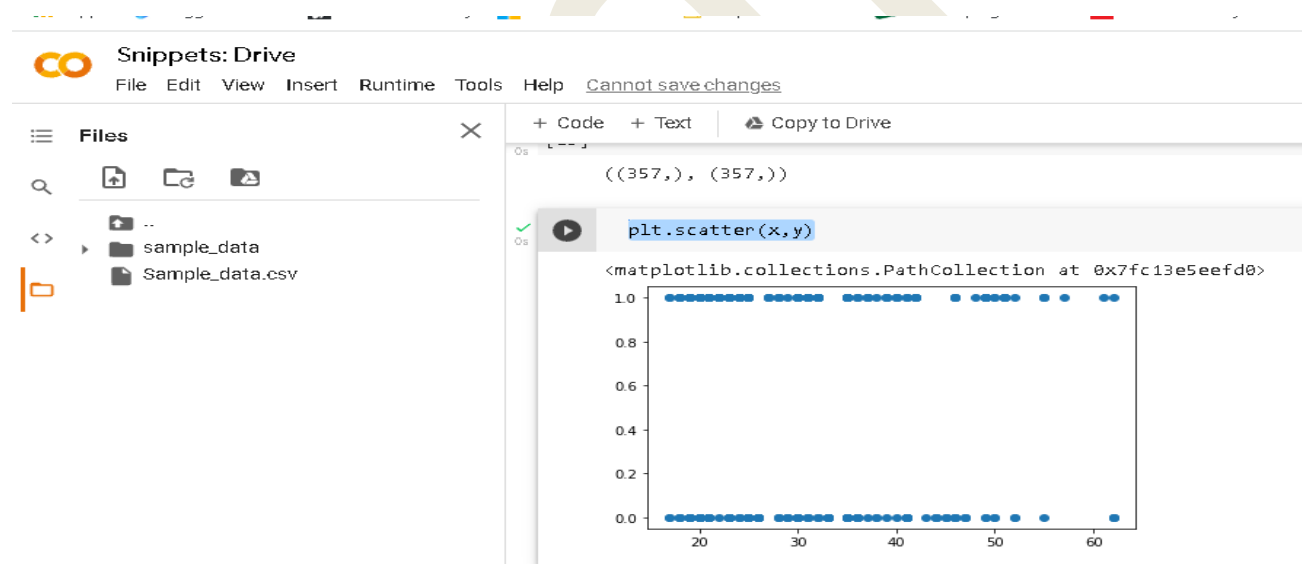
Source: Author

Use of classification for data mining to establish any relationships between inmates' demographics and crimes

One of the innovative ways to tackle crime is to leverage on machine learning models to discover hidden patterns or trends between inmates' characteristics and crimes for possible correlation. Even though such relationship may be influence by confounding variable and not conclusive, it could still help in the fight against crime. In line with the objectives a classification models were explored to determine whether the age of inmates has any relation with the category of crimes (petty or non-party). Kaggle data attached as appendix III was explored for this demonstration since the raw data of prisoners in Ghana could not be obtain due to security and privacy. Figure ... demonstrate the simple classification model considered to help predict age and crime category.

```
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
change.log x new 1 x Sleek Cuttings x my sandbox.txt x postgres query for import.txt x new 2 x new 3 x
1 #importation of key python packages
2 import pandas as pd
3 import matplotlib.pyplot as plt
4 from sklearn.linear_model import LogisticRegression , LinearRegression
5 from sklearn.model_selection import train_test_split
6 import numpy as np
7 from sklearn.metrics import confusion_matrix
8
9 #sample data obtain from kaggle imported
10 df = pd.read_csv("/content/Sample_data.csv")
11
12 #all null fields filled with 0
13 df.fillna(value=0, inplace= True)
14
15 #display the first 5 rows
16 df.head(5)
17
18 #data shape
19 (357, 45)
20
21
22 #classification problem was between age_at_arrest and Offence category (petty or non_petty)
23 x = df.age_at_arrest # Age at which offender was arrested
24 y = df.Offence_category_code # petty and not petty recorded as 0 and 1 in the dataset
25
26 plt.scatter(x,y)
27
28
```

Figure:... Simple scatter plot between age_at_arrest and offence_category



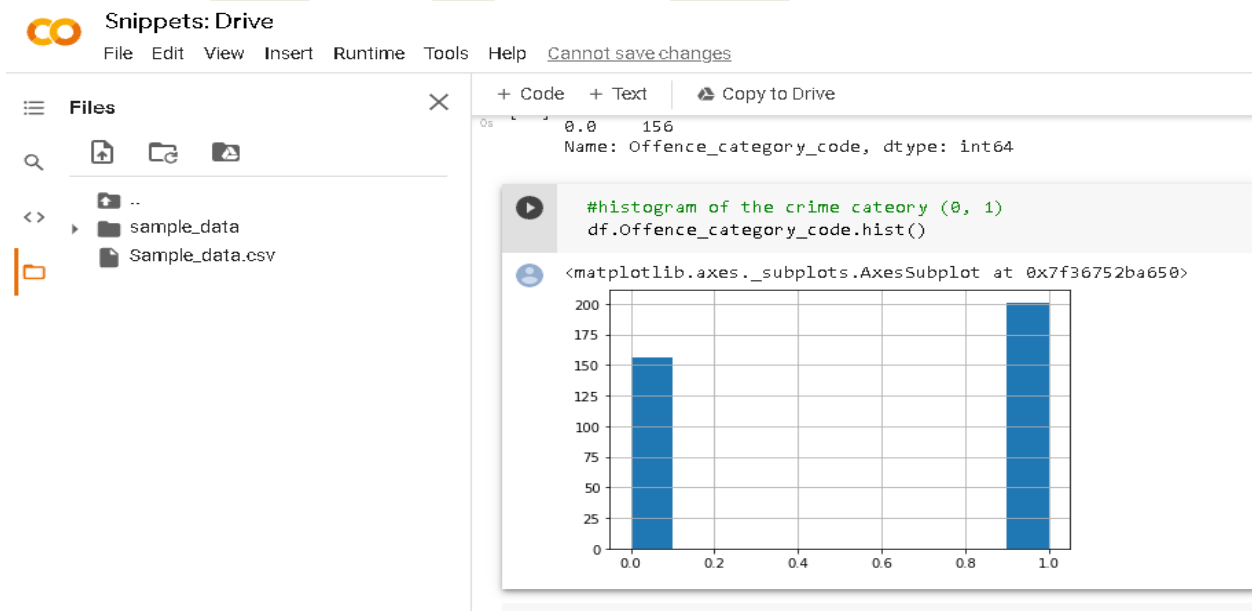
Since the problem is a classification problem, logistic regression was explored

Figure: ..

```
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
change.log x new 1 x Sleek Cuttings x my sandbox.txt postgres query for import.txt new 2 x new 3 x
28
29
30 #split of dataset for training and testing. 70% of the dataset used to train the mode and 30 % used for testing
31 x_train, x_test, y_train, y_test = train_test_split(df[['age_at_arrest']], df.Offence_category_code, test_size = 0.3)
32
33 #initialising the model
34 model = LogisticRegression()
35
36 #model trained
37 model.fit(x_train, y_train)
38
39 #training model used to predict the 30% dataset of age_at_arrest
40 y2 = model.predict(x_test)
41
42 #Testing reliability of model as accurate predictor of age_at_arrest and offence_category
43 model.score(x_test, y_test) # 0.527777 R2 values implied the model was not a good predictor between offenders age and crime category.
44
45 #Even though the training dataset was varied repeatedly, the R2 value generated each time was was low and unreliable
46
47 #histogram of the data_set considered crime category (0, 1)
48 df.Offence_category_code.hist()
49
50
51 #Checking the efficacy of the model in prediction (type 1 and type 2 errors)
52 confusion_matrix(y_test, y2)
53
54 array([[ 0, 51],
55        [ 0, 57]])
```

The confusion matrix in checking the type 1 and type 2 errors reveal where the model was to predict 1 for petty offence, it prediction had zero accuracy and when it was to predict non-party, it 51 errors as petty.

Figure: Histogram of the offence category considered for the classification model.



From the analysis, the model was abandoned since it could not serve as a good predictor of age_at_arrest and crime because R2 was low and the confusion matrix for type 1 and type 2 error

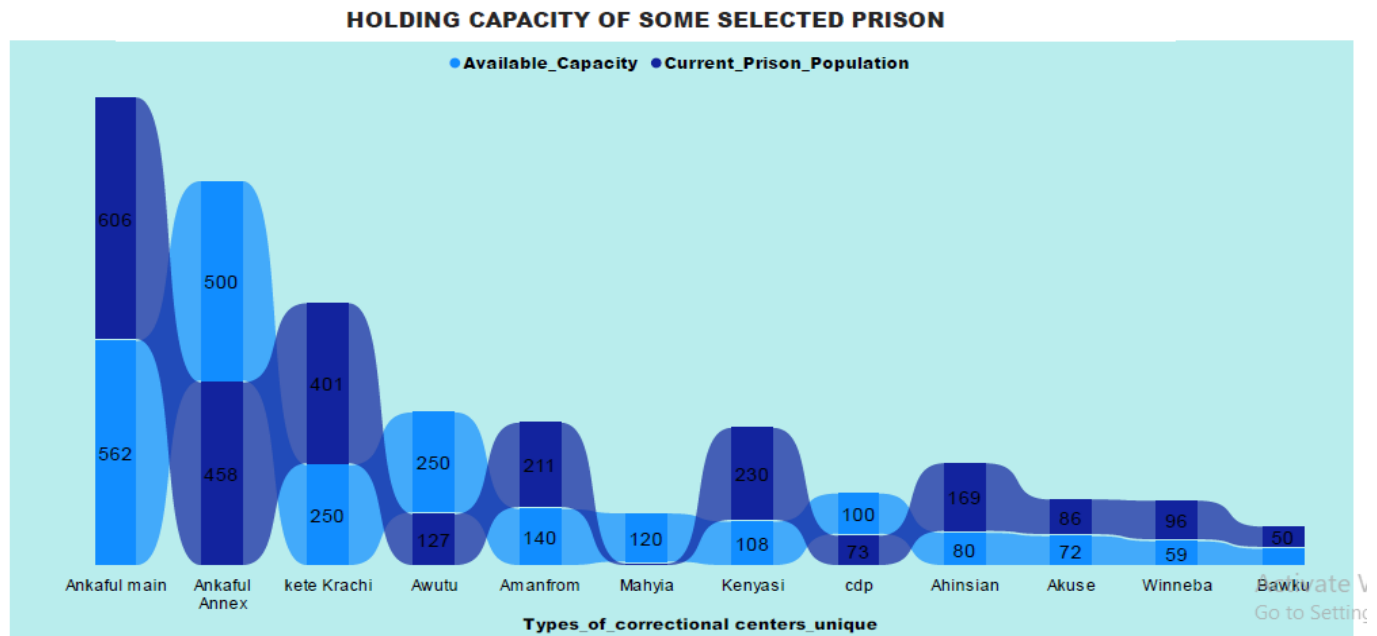
4.4 PREDICT GROWTH OF PRISON POPULATION FOR TIMELY INTERVENTION TO AVOID OVERCROWDING.

Overview of overcrowded and non-overcrowded prisons facilities

The ribbon chart in Figure 4.4 is one of the most reliable tools that could be deployed as a dashboard for operational tracking of overcrowding across all prisons nationwide in real time. The chart helps compare the available capacity to the current prison population and the overlapping colours categories quickly highlights whether a prison is overcrowded or not. When the **torea bay (Violet like)** ribbon overlaps on top it shows that the prison in reference is overcrowded, but when the light blue-ribbon overlaps, it shows that the prison in reference has available holding capacity or extra space.

For instance, the first ribbon in Figure 4.4 shows that the Ankaful main prison is overcrowded with 606 inmates above the holding capacity of 562. The level or extent of overcrowding in this case is 44 (606-562). The next ribbon also shows Ankaful Annex prison with less inmates (458) than the available holding capacity of 500. The difference between the available holding capacity and current prison population is 2 (500 – 458). This implies that when more than 2 prisoners are admitted the facility would exceed its threshold and get overcrowded. Since prison admission is hourly, daily, weekly or monthly phenomenon, the ribbon charts help accurately predict in real time when a facility exceeds its threshold. The use of Power BI direct query capability linked to centralised database from source for all the prison could help Ghana Prison Service Head Office monitor the level of overcrowding across all prisons nationwide in real time. This could help the service achieve their primary functions of ensuring safe custody of inmates by deploying remedial or IoT EM measures to avoid overcrowding which in severe situation could lead to death. The centralised database gets updated as and when prison facilities capture new admissions or exits of prison inmates. The chart in figure 4.4 could help key stakeholders immediately notice overcrowded facilities and intervene appropriately.

Figure 4 11 Ribbon Chart highlight specific facilities facing overcrowding challenges.



Source: Author

PRISON ADMISSIONS

Figure 4.3 provides prisoner admission rates over time. The record shows the average monthly admission rates for different years from 2015 to 2018. It is important to highlight that, even though the current available capacity of all prisons in Ghana is 9,945 based on the data provided by the Ghana Prison Service, the admissions over different periods was roughly average between a minimum of 1300 and a maximum of 15000 highlighting the level of overcrowding over time. Even though previous information revealed the level of overcrowding at 45%, the figure has fallen to 35% from the dataset received in 2021.

Table 4 3: Average monthly prison admission rates

Date	2015	2016	2017	2018
Jan	14737	14491	13067	13875
Feb	14710	14514	12978	14310
Mar	14631	14518	12943	14513
Apr	14418	14430	13120	14574
May	14224	14285	13199	14571
Jun	14225	14150	13330	14675
Jul	13973	13503	13435	14657

Aug	13928	13593	13492	14762
Sep	14060	13685	13764	15063
Oct	14323	13537	13767	15008
Nov	14369	13299	13759	15034
Dec	14533	13068	13733	14910

Source: Ghana Prison Service, 2018

PATTERN AND TRENDS OF PRISON ADMISSION IN GHANA

One of the key objectives of the study is to deploy a predictive time series model that could help prison administrators predict inmates' populations to enable them plan effective strategies to avoid overcrowding.. To achieve this objective, the Autoregressive Integrated Moving Average (ARIMA) model was considered to help deploy an effective time series forecasting.

The models according to Brownlee (2017) work as follows:

Autoregressive (AR): The dependent relationship between an observation and the number of lags

Integrated (I): The use of differencing raw observation (subtracting an observation from an observation at the previous steps)

Moving Average (MA): A model that uses the dependency between an observation and a residual error from a moving average model applied to lagged observations

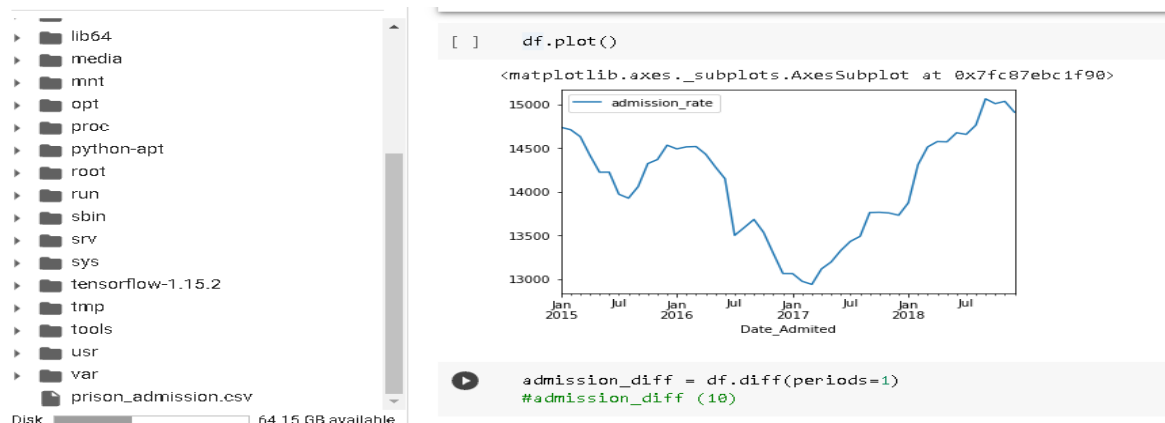
The dataset of the Ghana Prison service was recaptured as univariate dataset (date and admission_rate) and imported into google collab for ARIMA model using python as shown in Figure ...

```

1 #Key libraries imported for the ARIMA model
2 from matplotlib import pyplot as plt # to plot a scatter diagram
3 from pandas import datetime
4
5 #paser function created to help reformat the date into timestamp
6 def parser(x):
7     return datetime.strptime(x, '%Y-%m')
8
9
10 #Data read and the date column passed
11 series = pd.read_csv("/prison_admission.csv", index_col= [0], parse_dates= [0], date_parser= parser)
12
13
14 # sample data in the dataframe labeled as series displayed.
15
16 series.head(5)
17
18 Output
19
20 Date_Admitted    admission_rate
21 2015-01-01      14737
22 2015-02-01      14710
23 2015-03-01      14631
24 2015-04-01      14418
25 2015-05-01      14224
26
27 #Plot of the original time series graph
28 series.plot()
29

```

Figure.: Original model graph displayed



Source: Author

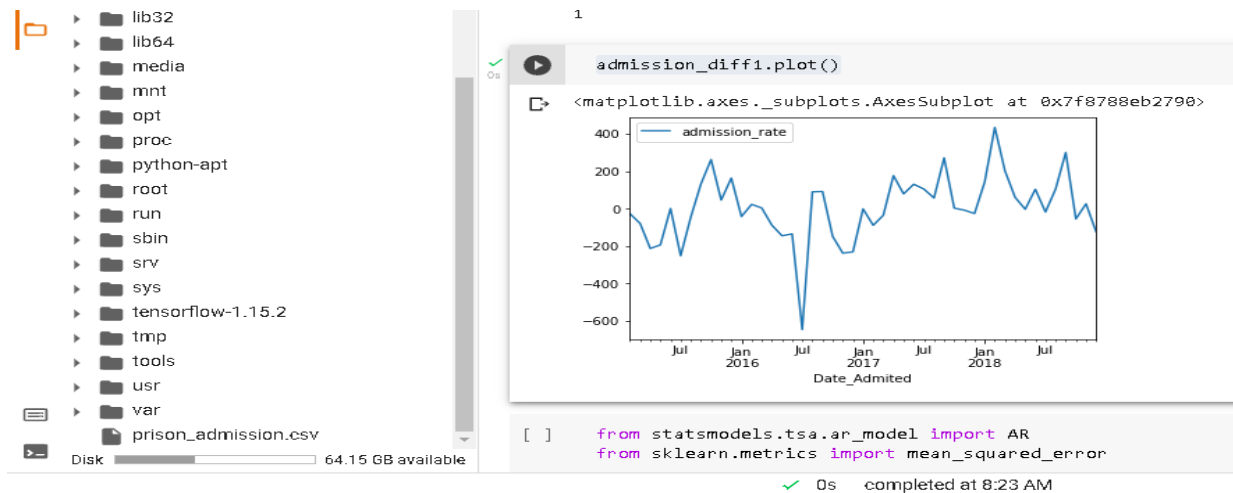
```

31 ##Integrating difference applied (subtracting an observation from an observation at the previous steps)
32
33 admission_diff = series.diff(periods=1)
34
35 admission_diff.head(5)
36
37 Output
38 Date_Admitted  admission_rate
39 2015-01-01      NaN
40 2015-02-01    -27.0
41 2015-03-01    -79.0
42 2015-04-01   -213.0
43 2015-05-01  -194.0
44
45 #Data adjusted to remove NaN and start from 2015-02-01 with -27
46 admission_diff1 = admission_diff[1:]
47
48 #importation of the plot_acf libraries from statsmodels.graphics.tsaplots subclass
49 from statsmodels.graphics.tsaplots import plot_acf
50 plot_acf(admission_diff1)

```

Figure: Stationary graph generated following the integration difference (subtracting the admission rates)

The stationary graph has its mean, variance and covariance constant over a periods

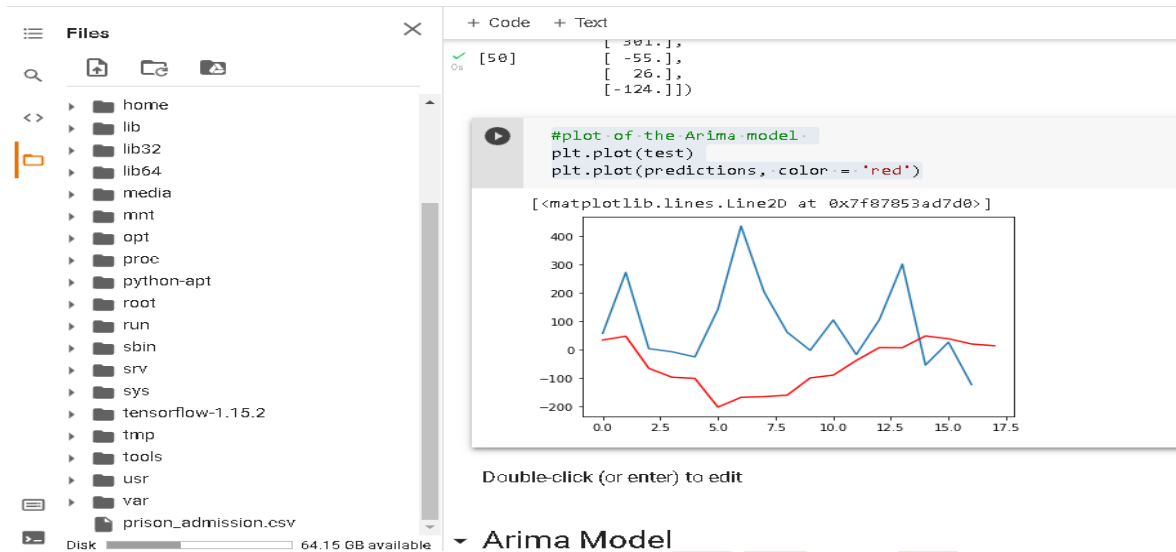


Source: Author

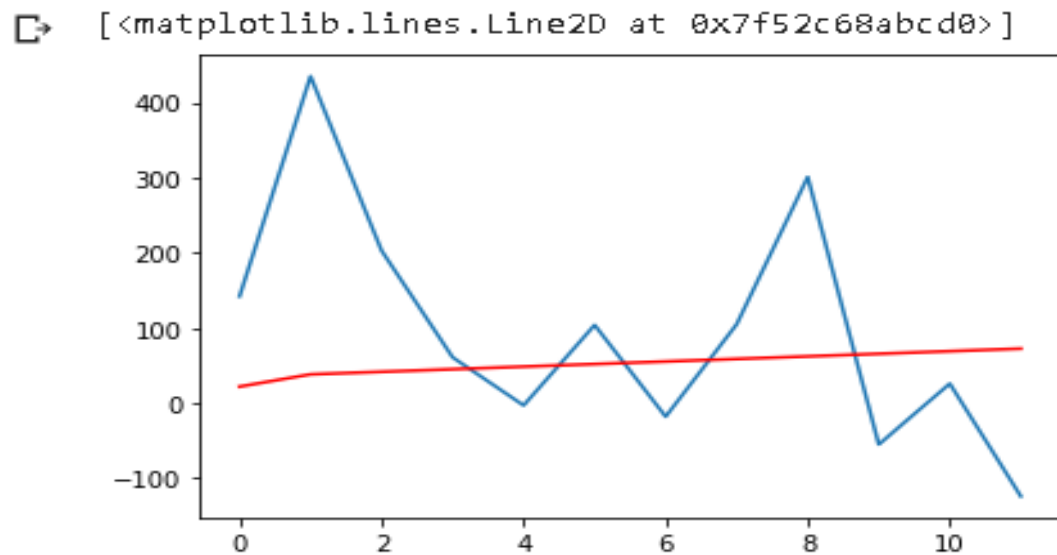
```

57
58
59 #importation of the Arima model library
60 from statsmodels.tsa.ar_model import AR
61 from sklearn.metrics import mean_squared_error
62
63 #shape of the admission_diff1 dataframe
64 admission_diff1.shape
65
66 Output
67 (47, 1)
68
69 #splitting the dataset for test and training
70 x = admission_diff1.values
71 train = x[0:30] # 35 dataset as train
72 test = x[30:] # 12 dataset as test
73 prediction = []
74
75 #model training
76 model_ar = AR(train)
77 model_ar_fit = model_ar.fit()
78
79
80 #model predictions
81 predictions = model_ar_fit.predict(start= 30, end = 47)
82 predictions
83
84
85 #plot of the Arima model
86 plt.plot(test)
87 plt.plot(predictions, color = 'red')

```



```
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
change.log x new 1 x Sleek Cutlins x my sandbox.txt x postgres query for import.txt x new 2 x new 3 x
94 #p = period taken for auto regressive model
95 # d = integrated order difference
96 # q = period in moving average model
97
98 #Model prediction base on Arima p specifying the period of time taking for prediction
99 #d integrating different
100 #q period in moving average model
101 model_arima = ARIMA(train, order = (0,1,1))
102 model_arima_fit = model_arima.fit()
103 model_arima_fit.aic
104
105 output
106 454.1282342944703
107
108 #forecasting 12 ahead
109 predictions = model_arima_fit.forecast(steps = 12)[0]
110 predictions
111
112
113 #Final graph plotted
114 plt.plot(test)
115 plt.plot(predictions, color = 'red')
116
117
```



4.5 PROPOSED IOT ELECTRONIC MONITORING SOLUTIONS

The proposed IoT electronic monitoring device would rely on a micro embedded subscriber identity module (e-SIM) for data and communication through the NB-IoT channel. In this case, communication of prisoner location outside prison facility would be achieved through the Cellular Network which is much more efficient, and the e-SIM chipset is also portable and fit for miniature IoT EM monitoring devices. The reliance on the NB-IoT frequency channel is to guarantee to prolong battery life which is a major challenge with existing Electronic Monitoring devices.

Also, the miniature IoT technology to be deployed would have fingerprint authentication programmed using python raspberry pie to help validate the offender periodically. The orange cover would have the reader to validate offenders figure print periodically. The watch-like nature of the device would be more convenient and less embarrassing which is one of the ethical concerns raised with some of the EM devices.

Figure 4 12Proposed Wristlet Electronic Monitoring Device

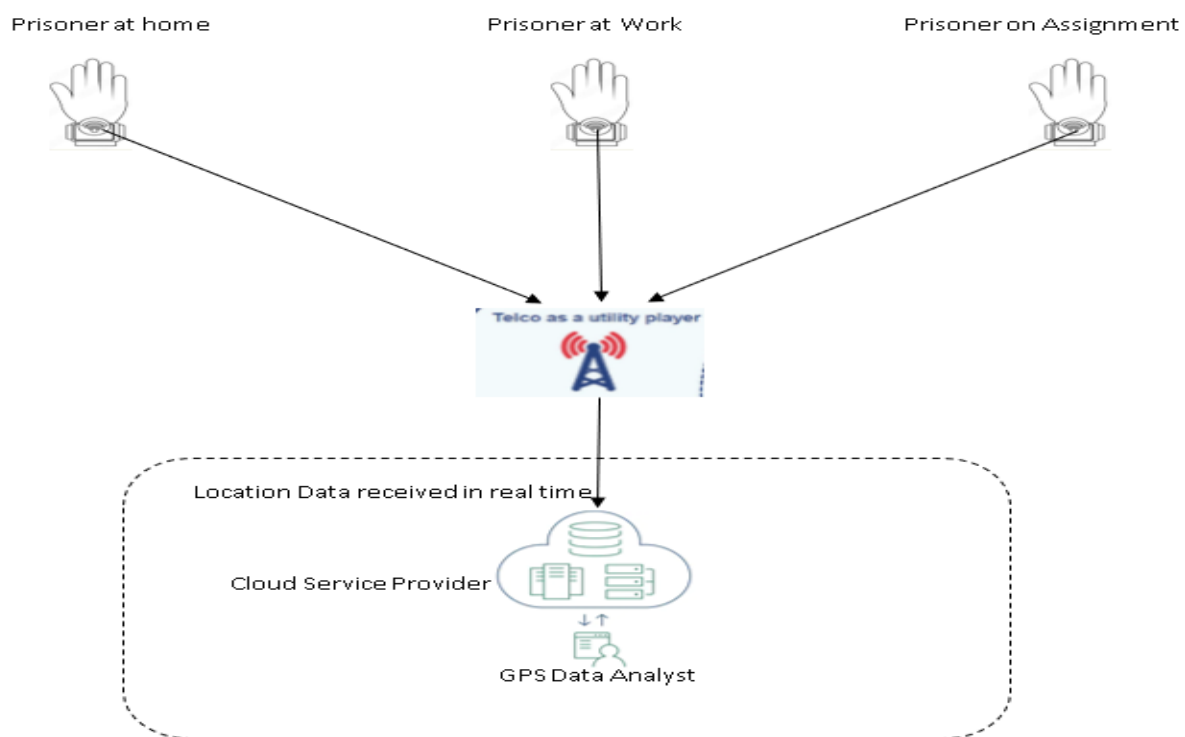


Source: <http://www.blackcreekisc.com/rtls.html>

Component view diagram

Figure 4.14 is the component view diagram of the proposed IoT EM monitoring solution for the Ghana Prison Service. The visualised model gives a comprehensive insight on how the proposed IoT EM device could be deployed and operationalised.

Figure 4 13 Component Diagram of the proposed prison concept



Source: Author

4.6 ESTIMATE OF COST BENEFITS ANALYSIS OF THE PROPOSED IOT EM DEVICE

Detail cost benefit Analysis (CBA)

The study considered the cost implication of implementing the proposed IoT EM model juxtaposed with the current with the extra cost incurred by the Ghana Prison Service in holding petty offenders behind bars.

The cost estimates for holding petty offenders (4800) identified in this study was computed as follows:

In 2018, the total staff strength of the Ghana Prison Service was 6163 with personnel emolument cost of **196,987,088.4 cedis p. a representing \$33,963,291.10**. Since the 6163 staff (uniform and non-uniform personnel) were employed to cater for the entire 13,480 inmates nationwide, it implies that the 4800 petty offenders identified based on estimated provided by the Ghana Prison Service accounted for 2195 extra prison officers for optimum operation. The emolument for the 2195 extra personnel translates to 70,158,471.36 cedis p.a representing **\$ 12,096,288.16**. But the cost was halved as shown in table .. because even when IoT EM option is deployed, we assume half of the prison officers would be required to augment the smooth operation of the technology.

The other recurrent basic expenditure born by the prison service in holding 4800 petty offenders behind bars was computed as follows:

Cost estimates for basic needs (food, sanitations, health, water, utilities) as provided by the Ghana Prison Service to cater for 13480 inmates was 14,164,131.6 cedis p.a translating to **\$ 2,442,091.66**. Therefore, using cross multiplication, the extra cost incurred on 4,800 petty offenders can estimated as **\$ 869,587.53** as captured in table ... Emolument cost and basic cost estimates were the two main recurrent expenditure considered for holding extra inmates behind bars.

Also, the cost estimates for the proposed IoT solution were computed as follows:

Cost of cloud service using Google Cloud estimates:

Long term storage cost per TB was \$ 20 which translate to \$ 240 per annum

Processing cost at flat rate pricing for data was \$1700 which translate to \$20,400 per annum

Data cost for IoT devices and control center using local service provider rate: 672.67 per month which translate to \$ 8,072 per annum.

Estimated cost for proposed IoT device as provided by Mantrac was 100 dollars per device which gives a total of $4800 * 100$ for all petty offenders translating to \$480,000.

The cost of software for monitoring offenders in real time was estimated as \$15000 with maintenance fees of 10% per month which translate to \$ 33,000 p. a

All the estimates are captured in table . for ease of comparison.

Estimates of deploying IoT	Unit Cost (\$)	Total per Month / Size (\$)	Annual Cost (12) (\$)
Cloud Service: Google cloud estimates			
Storage Cost: Long term storage per month	0.010 per GB	20 per TB	240
Processing Cost: Flat Rate pricing for data		1700	20,400.00
Data Cost : Average cost of unlimited data package in Ghana @ 60 MPS		672.67	8,072.00
Data for devices chips			
IoT EM Device Cost :	100	100 * 4800 potential petty offenders	480,000.00
Application panel for monitoring	15000 \$ at 10% maintenance fee	1500	33,000.00
Total			541,712.00
Estimates of extra cost of incarcerating petty offenders			
Basic Cost of holding inmates in prison		2,360,688.60	869,587.53
Emoluments of Extra Personnel to manage petty offenders			6,048,144.08
Total			6,917,731.62

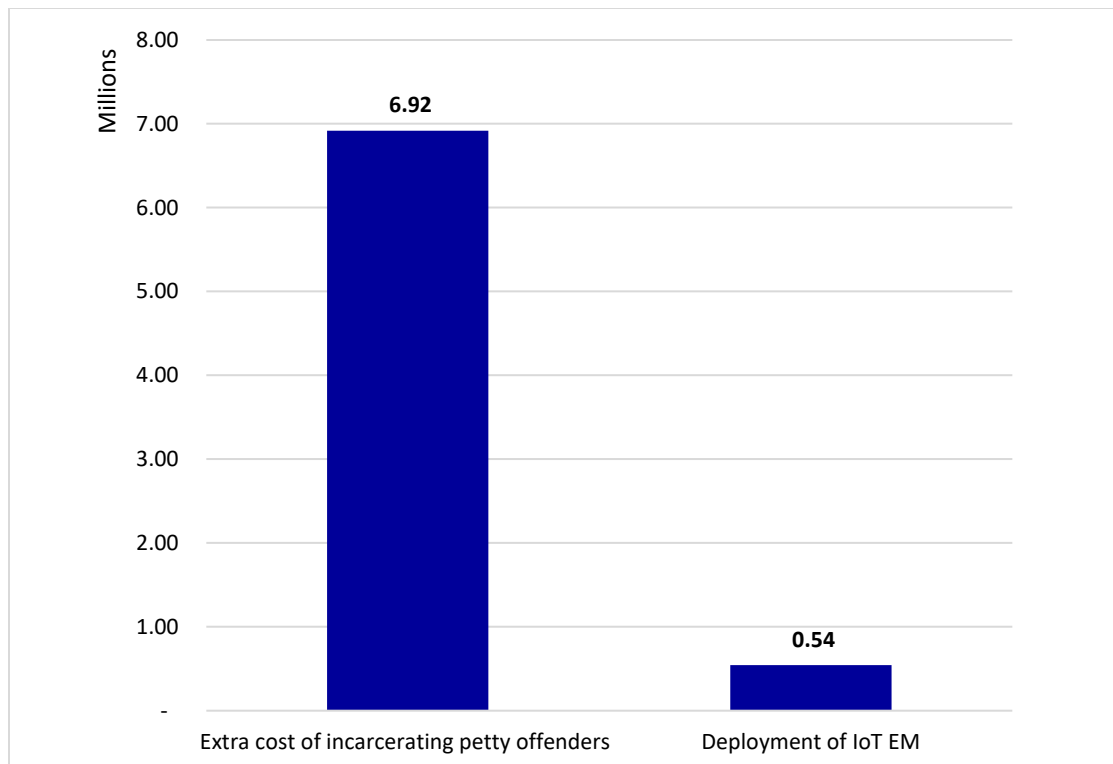
Source: GoG payroll, Google Cloud Pricing and Ghana Prison Service

The cost-benefit analysis of the proposed IoT EM option was considered in these studies and juxtaposed with the cost of implementing the device. Some key assumptions were made to ensure that the cost reflects the maximum expenditure possible in the case of the proposed IoT reforms.

Table 4 4:Cost estimates of current prison management and proposed IoT solutions

From the cost estimates or aggregate in Figure 14, the IoT EM option \$ 0.54 Million and cost-effective compare with the existing cost of \$ 6.92 Million incurred on keeping petty offenders behind bars. It, therefore, makes economic sense to adopt the proposed option where prisoners would take care of themselves and cut the cost incurred basic needs and recruiting personnel to manage overcrowded prisons.

Figure 4 14 Cost estimates of IoT EM option juxtaposed with extra cost of incarcerating of petty offenders



Source: Author

Potential Benefits of the proposed IoT EM model

The proposed IoT electronic monitoring prison management can serve as a one-stop solution for managing several prisoners at the same time using few officers as shown in the component diagram and by focusing on petty offenders, the danger to society would also be minimum.

Inhumane conditions in prison due to overcrowding would reduce significantly and offenders who are breadwinners of their families can work and still cater for their families whiles under monitoring. This could go a long way in addressing the vicious cycle of amplifying offenses when breadwinners are incarcerated for petty offenses without any social support system forcing some families to resort to dubious ways for survival. The pressure on prison administrators would also reduce significantly since they would have fewer prisoners to manage the predictive analysis of location data, offences and other variables that could help provide proactive solutions in reducing crimes and informed data-driven policies focused on specific communities.

5.0 CONCLUSION ANDRECOMMENDATION

5.1 INTRODUCTION

This chapter provides the conclusions drawn from the analysis of the data collected from the survey. The discussion of key research objectives and practical analysis of the recommendations and cost implications. Consideration of the limitation of the study and highlights future research options or alternatives. Based on the findings, discussions, and conclusions arrived at some recommendations have been made in this chapter.

5.2 GENERAL CONCLUSIONS

The overall aim of this research was to advance knowledge and understanding of how IoT electronic monitoring devices could be deployed in addressing prison overcrowding challenges

focusing on petty offenses in Ghana and possible replication of same in areas with similar challenges. To achieve this aim, the following specific research objectives were considered:

- Investigate the underlying causes of over overcrowding in Ghana's prison system.
- Gather secondary data and study patterns and trends of crimes committed in Ghana over a certain period.
- Predict growth of prison population for timely intervention to avoid overcrowding.
- Establish how IoT intervention could be deployed in managing petty offences to address overcrowding in Ghana's prison system and review the feasibility of tracking petty offenders.
- Estimate Potential cost-benefits analysis of the system when deployed.

The study has extensively answered the research objectives in line with the purpose of the study. Investigation of the factors directly contributing to prison overcrowding was explored and identified. These included large areas, high sentencing regimes, petty offenses among others. Having determined the key issues causing prison overcrowding, the potential impact of implementing an IoT intervention was considered which showed a significant reduction in overcrowding. In all, the IoT EM option could be deployed to impose a non-custodial sentence for 4,800 inmates outside the prison facility which can significantly reduce overcrowding and address issues of disproportionate use of prison.

The study justified extensively why the research was necessary and urgent to serve as a pragmatic approach to resolving prison overcrowding challenges. In all, 8 petty offenses were identified and the deployment of the proposed reforms using IoT EM could rescue 4800 inmates wasting their lives behind bars due to petty offenses. The use of the IoT option could create an extra space of 0.13% revealed in the findings when deployed to provide a non-custodial sentence for petty offenders.

Also, in this study, the potential to leverage geospatial big data to predict and control crime particularly at various hotspots was demonstrated. Even though the impact of this option could take time due to the lack of available geospatial datasets on offenders, the adoption of IoT with the potential to generate this data would change the dynamics for more intelligence prison management in collaboration with other agencies.

Furthermore, conducting a cost-benefit analysis of the proposed solution and the extra cost of incarcerating the offenders in prison revealed that the IoT option is more cost-effective compared with incarcerating those petty offenders. This is one of the compelling reasons why IoT EM options should be considered.

5.3 RESEARCH OBJECTIVES CONCLUSIONS

Even though countries across the globe are increasingly adopting EM options in managing offenses as highlighted in the literature, the adoption of the same by the Ghana Prison Service could only be possible based on a compelling reason. Therefore, the study sought to understand the nature of overcrowding and the underlying causes to appreciate the impact of the use of IoT EM in Ghana's

prisons. The finding revealed the impact and depth of petty offenses contributing to overcrowding in Ghana's prison system for which reason the deployment of IoT could be a game-changer. The rollout of the IoT electronic monitoring option would be a great boost to prison management and help address the disproportionate use of prison for petty offenses and as well address prison overcrowding. Therefore, the key research objective of understanding the underlying causes of overcrowding was extensively covered and the impact of the proposed solution was analyzed comprehensively. Without comprehensive data and analysis of the situation as a form of a feasibility study, it would be difficult to ascertain the effectiveness of the proposed solution.

The findings in this study show that the proposed IoT Electronic Monitoring option when successfully implemented could help significantly improve prison administration in Ghana and assuage the current level of prison overcrowding. The focus of this research on petty offenses and the need to empower the prison administrators to deploy alternative prison sentencing options will help key stakeholders in charge of prison administration adopt more effective measures towards prison management.

One of the key highlights in the findings was the potential to generate geospatial data from IoT devices to help predict, monitor, and prevent crime as espoused by Esri and other researchers. This option was thoroughly explored and demonstrated in the analysis and findings. With GIS mapping, a comprehensive analysis of patterns, relationships, and clusters between geospatial data and other data points can help inform decisions on crime.

A further drill down on activities focused on specific offenses resulting in the isolation and incarceration of inmates. The classification of the offenses into petty and non-petty offenses guided by Ghana's criminal code 1960 (Act 29) shared insight on the impact of the study in addressing prison overcrowding challenges when petty offenders are freed. This group constitutes a significant proportion of the current prison inmates' population with the current overcrowding rate estimated at 35%. It is obvious that investment in alternative prison options such as the IoT EM device can help stem overcrowding significantly and as well address the vicious cycle of crime caused by negative

Also, one of the key elements in this study was the nature of the proposed IoT EM option. The proposed tamper-proof wristlet options and its components considered under the action research strategy bring more clarity about the exact solutions being pursued in addressing an urgent and pressing issue of prison overcrowding challenges in Ghana. The component diagram further highlights the framework of the deployment and gives clarity on the cost-benefit analysis. The section on cost is important because, if the proposed solution is not cost-effective adoption at scale would be challenging and the essence of the research will be defeated. It is, therefore, possible for prisons facing similar challenges to pursue the same options.

5.4 RECOMMENDATIONS

Based on the findings, discussion, and analysis in this study, the following recommendation was arrived at:

The Ghana Prison Service should consider as a matter of urgency the proposed IoT EM reforms to address the urgent problem of overcrowding challenges and disproportionate use of prisons for petty offences. The reforms would encourage citizens to appreciate the justice delivery system as a tool for building progressive societies and dissuade the general perception that the legal system is being used to marginalise the poor and vulnerable in society which does not promote good governance and democracy.

The youthful nature of the inmates with over 52% constitution teens and youth should be a major concern to policy makers since these groups constitute the active workforce. Stakeholders in the interim could rely on the heat maps to take an inform youth policy initiatives targeting specific crime zones that would keep the youth engage in productive activities and stay away from certain offences identified as hotspot for such crime. The location base informed youth policies or initiative would be enriched with the availability of geospatial data in future.

The Ghana prison service must institute measures to update the Gate Journal source documents on prisoner characteristics to include prisoner classification as petty or non-petty. The creation of the variable would help in the identification and classification of petty offenders with ease. This would help facilitate the deployment of proposed solution as and when necessary.

The deployment of the IoT EM reform can be done at the prison level by bringing together key stakeholders playing critical roles in the justice delivery process to take an informed decision and impose non-custodial sentences on petty offences. This option is ideal because the prison service has first hand information about the effect of overcrowding in their facilities and the process is more consultative. However, the IoT EM option can also be deployed as suspended sentence in court particularly for offenders who are unable to pay their fines.

Cost effectiveness:

acknowledge by key stakeholders such as the President and the former Chief Justice since it has the potential address overcrowding significantly by rescuing at least 4800 petty offenders constituting 40.6% of the inmates population. Based on the analysis, the inmate's population would reduce from 13K to 8K leading to excess prison capacity of 0.32% for serious crimes or offences.

The adoption of the IoT EM option is also cost effective and addresses the budgetary constraint of the Ghana Prison Service since the proposed option is far less expensive than the recurrent expenditure born out of holding petty offenders.

Pandemic Escape and panic releases. (Digitisation)

Prison across the globe should focus their attention on innovative IoT reforms as proposed in this study. Since that option is a more cost-effective and ideal solution to escape devastating pandemics such as COVID 19.

The World Prison System could adopt this research and enhance it to address challenges of overcrowding and injustices emanating from some parts of the globe. This could facilitate the attainment of SDG goal 16.3 and 16.3.2.

Centralized agencies such as the World Prison System could consider adopting similar prison reporting templates to gather more insightful information on prisons across different countries in pursuit of attaining sustainable development goals 16.

There is the need for the government of Ghana to consider the proposed solution drawing on the possible insight of offenses and location in crafting data-driven policies to combat crimes.

Considering the youthful prison population, the government would have to rely on data from Ghana Prison Service to inform its social policies targeting the youth.

Government and other key stakeholders should extract data on petty youth offenders to strategize youth centred policies at strategic location where teens and youth crime rate are high. The heat map at this stage could help but the geospatial data intervention would be more focus oriented.

Further extensive studies can be explored to understand the insignificant number of female populations in prison for lessons learnt to be applied in reducing the high number of male populations in prison

5.5 ERRORS AND LIMITATION

The focus of the research to introduce significant reforms and transformation in the management of prisons in Ghana to serve as a lesson for some part of the world broadens the scope of the research and exposes the study to some errors and limitations identified as follows:

Errors

One of the key errors in this study could be linked to the classification of petty and non-petty offences. Even though the prison service data captured an ideal percentage of crime across facilities that could be considered as petty, the database does not have a variable to tag offences as petty at the point of data collection. Therefore, the proposed percentage might not accurately reflect the exact number of petty offences.

Also, there was slight variation in the total number determine as petty offenders using the proposed % received from the prison service and the classification of offences. The difference is unavoidable since the

data used for the petty offence classification was compiled in 2018 and the data used % classification of petty offence was received in 2021.

Limitations

Prison admission and exit of prisoners is a routine phenomenon and therefore without a strict cut of date for data received, there would be inconsistencies in the dataset used for presentation. However, due to the challenges of the dataset, this key factor could not be considered. But the impact on the study was minimal.

Also, one of the key limitations of the study was the lack of direct access to prison facilities to investigate and ascertain the nature and extent of overcrowding in some prison facilities. This challenge was mainly due to the COVID 19 pandemic and lack of resources inhibiting physical access and travels to access some of the prison facilities.

5.6 RECOMMENDATIONS FOR FURTHER STUDY

The findings in this study give hope on how potential geospatial big data solutions on crime could be explored. This critical area should be further explored in future research. The data generated can be related to other data sources highlighted as crime matrix below.

REFERENCES

- United Nation Office on Drugs and Crime, 2013. Handbook on Strategies to Reduce Overcrowding In Prisons. Viena, New York, [online] Available from https://www.unodc.org/documents/justice-and-prison-reform/Overcrowding_in_prisons_Ebook.pdf [Access date 12 January, 2021]
- Commonwealth Human Right Initiative, 2018. Decriminalizing and Declassifying Petty Offences In Ghana. (Online) Available from <https://www.humanrightsinitiative.org/publication/decriminalising-and-declassifying-petty-offences-in-ghana> [Accessed date 20th July 2021]
- Penal reform international, 2015. Guidance Document on the Nelson Mandela Rules Implementing. The United Nations Revised Standard Minimum Rules For The Treatment Of Prisoners. Available from https://cdn.penalreform.org/wp-content/uploads/2018/07/MR_Guidance_Doc.pdf [Access date 3rd March, 2021]
- Reno, J., Marcus, D., Leary, M. L., Gist, N. E., 2000. A Second Look at Alleviating Jail Crowding: A Systems Perspective. Washington, DC. [Online]. Available from <https://www.ojp.gov/pdffiles1/bja/182507.pdf>. [Accessed date 4th May 2021]
- Perfector of Sentiments Foundation. [online]. Available from <http://posfoundation.org/about/> [Access date 18th July 2020]
- Acquah J., Boateng A., Brew L., 2018. Comparative Study of Mathematical Models for Population Growth in Ghana Prisons”, Ghana Journal of Technology, Vol. 3, No. 1, pp. 25 - 30.
- Malloy G., Puglisi L., Brandeau M., Harvey T., Wang E., 2020 Depopulate, single cell, Test: Finding the evidence base for strategies to control COVID-19 transmission in a large urban jail. Available from <https://www.penalreform.org/blog/depopulate-single-cell-test/> [Access date April, 2021]
- Ghana Prison Service [online] Available from <http://www.ghanaprison.gov.gh/brief.html#:~:text=Brief%20History%20of%20the%20Ghana%20Prisons%20Service&text=By%201841%2C%20a%20form%20of,who%20were%20kept%20in%20chains.> [Access on 20th December, 2020]
- Crime Museum, ca 2017. [online] Available from <https://www.crimemuseum.org/crime-library/famous-prisons-incarceration/> [Access on 18th July 2020]
- Wood G., 2010. Prison without Walls-Magazine-The Atlantis. [online] Access from <https://www.theatlantic.com/magazine/archive/2010/09/prison-without-walls/308195/> [Access date 02 February, 2021]

Nellis M. 2015. Standards and Ethics In Electronic Monitoring. Handbook For Professionals Responsible For The Establishment And The Use Of Electronic Monitoring. [online] Available from <https://rm.coe.int/handbook-standards-ethics-in-electronic-monitoring-eng/16806ab9b0> [Access date 24th May 2021]

Budinski M., Berat N., 2019. IoT Use Cases in Prisons: From a Dusty Lockup to a “Smart Penitentiary Facility” Available from <https://wolkabout.com/blog/smart-penitentiary-facility/>. [Access on 15 July, 2021]

Braun 2019 A.. The Internet of Prisons: IoT Is Changing How People Do Time. [online] Available from <https://www.iottechrends.com/the-internet-of-prisons-iot/#:~:text=One%20of%20the%20most%20obvious,the%20future%2C%20an%20injectable%20microchip.> [Access on 20th December 2020]

Bhatta T. P., 2018. Case Study Research, Philosophical Position and Theory Building: A Methodological Discussion. Dhaulagiri Journal of Sociology and Anthropology 12:72-79. Available from https://www.researchgate.net/publication/330798170_Case_Study_Research_Philosophical_Position_and_Theory_Building_A_Methodological_Discussion

Modern Ghana, 2020. Gov't To Tackle Overcrowding In Prisons. [online] Available from <https://www.modernghana.com/news/984819/govt-to-tackle-overcrowding-in-prisons.html> [Accessed date 30th May, 2021]

Crime Check Foundation. [online] Available from <https://crimecheckfoundation.org/2097-2/> [Access date 21st December 2020]

The Danish Institute for Human Right, ca 2021. The Human Rights Guide to the Sustainable Development Goals. [online] Available from [https://sdg.humanrights.dk/en/targets2?goal\[\]=85&target=16.3](https://sdg.humanrights.dk/en/targets2?goal[]=85&target=16.3) [Access date 17th June, 2021]

Business Ghana, 2018. Many reforms in the justice delivery systems are long overdue-CJ [online] Available from <https://www.businessghana.com/site/news/general/174196/Many-reforms-in-the-justice-delivery-systems-are-long-overdue-CJ> [Access date 18th September, 2021]

M. Saunders and P. Tosey, 2011. The Layers of Research Design.

Clark J. S., Porath S., Thiele J., Mjobe, 2020. Action Research. New Prairie Press, ISBN: 978-1-944548-29-2 (online) Available from <https://newprairiepress.org/cgi/viewcontent.cgi?article=1034&context=ebooks>. [Access on August 1st, 2021]

Abu-Bashal A., 2020. Ghana pardons 794 prisoners to curb spread of COVID 19. [online] Available from <https://www.aa.com.tr/en/africa/ghana-pardons-794-prisoners-to-curb-spread-of-covid-19/1898022> [Access date 7th March, 2021]

Graham H., Molvor G., 2017. Electronic Monitoring In The Criminal Justice System. [Online] Available from <https://www.iriss.org.uk/resources/insights/electronic-monitoring-criminal-justice-system> [Access date 18th September, 2021]

Reagan JR, 2017. The impact of electronic monitoring and disruptive innovation on recidivism rates in federal prisons: a secondary data analysis. *BiomBiostat Int J.* 2017;5(4):125-130. DOI: 10.15406/bbij.2017.05.00138 [Online] Available from <https://medcraveonline.com/BBIJ/the-impact-of-electronic-monitoring-and-disruptive-innovation-on-recidivism-rates-in-federal-prisons-a-secondary-data-analysis.html> [Access date 15th August, 2021]

Albrecht H. J., 2005. Electronic Monitoring in Europe A Summary and Assessment of Recent Developments in the Legal Framework and Implementation of Electronic Monitoring [Online] Available from <https://static.mpicc.de/shared/data/pdf/albrecht.pdf> [Access date 12th June, 2021]

M. Nellis, 2020. The convergence of information technology and operational technology in Corrections: a driver for innovation [online] Available from <http://justice-trends.press/the-convergence-of-information-technology-and-operational-technology-in-corrections-a-driver-for-innovation/> [Access on 6th January, 2021]

Ouagadougou declaration on Penal and Prison Reform ,2002. [Online] Available at <https://www.southernafricalitigationcentre.org/wp-content/uploads/2017/03/Ouagadougou-Declar.pdf> [Access on 20th June 2021]

Royo M. G., Parikh P., Belur J., 2020. Using heat maps to identify areas prone to violence against women in the public sphere [online] Available from <https://crimesciencejournal.biomedcentral.com/articles/10.1186/s40163-020-00125-6> [Access date July, 2021]

Li W., Radke J. D., 2012. Geospatial data integration and modeling for the investigation of urban neighborhood crime [online] Available from <https://www.tandfonline.com/doi/full/10.1080/19475683.2012.691903> [Access date 15 August, 2021]

Bartels L., Martinovic M., 2017. Electronic monitoring: The experience in Australia. *European Journal of Probation.* [online] Available from <https://journals.sagepub.com/doi/pdf/10.1177/2066220317697658>

[Access date 15 August, 2021]

Belur J. Thornton A. Tomson L. Manning M., 2020. Systematic review of the effectiveness of the electronic monitoring of offenders. Journal of criminal justice. London.

Max. W., 1993. Walking prisons The Futurist; Washington Vol. 27, Iss. 4, page 34

Drake G. B., 2012. Developing a Successful GPS Offender Tracking Program

Rane V. Gawde V. H. Kushwaha H. S. Masalia N. M. Panchal T. R 2019. IoT prison break alerting and monitoring system (P-BAS). Parama research journal. Volume 9, Issue 2

National Institute of Correction, ca.2020. Technology in Correction. Available from <https://nicic.gov/technology-corrections>

Bulow W. O'Nils, 2013. Electronic Monitoring of Offenders: An Ethical Review.

Esri, 2012. From the Cell to the Streets: GIS for Probation, Parole, and Corrections

Panelli J., 2018. Ethics of Predictive Policing. Viterbi School of Engineering, University of Southern California

Ghana's Criminal Offence Act 1960 (Act 29)

Brownlee J., 2017. How to Create an ARIMA Model for Time Series Forecasting in Python. [Online] Available from <https://machinelearningmastery.com/arima-for-time-series-forecasting-with-python/> [Access date 2nd October, 2021]

APENDICES

Appendix I

Prison_category	Types_of_correctional centers	Definition_of_p rison_types	Available _Capacit y	Current_ Prison_P opulation	Level_of_Overcro wding
Senior Correctional Center	Senior Correctional Center	Low Risk	340	227	Not Overcrowded
Central Prison	Kumasi central	High Risk	416	1914	Overcrowded
Central Prison	Sunyani central	High Risk	430	888	Overcrowded
Central Prison	Tamale male	High Risk	78	301	Overcrowded
Central Prison	Navrongo	High Risk	108	103	Not Overcrowded
Central Prison	Ho male	High Risk	170	369	Overcrowded
Central Prison	Sekondi male	High Risk	412	568	Overcrowded
Central Prison	Wa	High Risk	50	164	Overcrowded
Local Prisons	Obuasi Local	Moderate To	100	166	Overcrowded
Local Prisons	Mahyia	Moderate To	120	3	Not Overcrowded
Local Prisons	Koforidua	Moderate To	300	596	Overcrowded
Local Prisons	Gambaga	Moderate To	46	28	Not Overcrowded
Local Prisons	Yendi	Moderate To	120	69	Not Overcrowded
Local Prisons	kete Krachi	Moderate To	250	401	Overcrowded
Local Prisons	Salaga	Moderate To	30	33	Overcrowded
Local Prisons	Bawku	Moderate To	40	50	Overcrowded
Local Prisons	Kpando	Moderate To	150	105	Not Overcrowded
Local Prisons	Tarkwa	Moderate To	100	325	Overcrowded
Local Prisons	Winneba	Moderate To	59	96	Overcrowded
Local Prisons	Ankaful Annex	Moderate To	500	458	Not Overcrowded
Local Prisons	Akuse male	Moderate To	60	76	Overcrowded
Local Prisons	Yeji	Moderate To	250	83	Not Overcrowded
Local Prisons	Ekuasi	Moderate To	144	76	Not Overcrowded
Female Prisons	Kumasi female	Moderate To	30	21	Not Overcrowded
Female Prisons	Sunyani female	Moderate To	60	16	Not Overcrowded
Female Prisons	Akuse female	Moderate To	12	10	Not Overcrowded
Female Prisons	Nsawam female	Moderate To	200	67	Not Overcrowded
Female Prisons	Tamale female	Moderate To	6	7	Overcrowded
Female Prisons	Ho female	Moderate To	18	9	Not Overcrowded
Female Prisons	Sekondi Female	Moderate To	30	14	Not Overcrowded
Open Camp Prisons	Ankaful main	Minimum Risk	562	606	Overcrowded
Open Camp Prisons	James Camp	Minimum Risk	560	233	Not Overcrowded
Open Camp Prisons	cdp	Minimum Risk	100	73	Not Overcrowded
Agricultural Settlement	Kenyasi	Minimum Risk	108	230	Overcrowded
Agricultural Settlement	Duayaw Nkwanta	Minimum Risk	150	154	Overcrowded
Agricultural Settlement	Ahinsian	Minimum Risk	80	169	Overcrowded
Agricultural Settlement	Ejura	Minimum Risk	70	81	Overcrowded
Agricultural Settlement	Amanfrom	Minimum Risk	140	211	Overcrowded
Agricultural Settlement	Awutu	Minimum Risk	250	127	Not Overcrowded
Agricultural Settlement	Forifori	Minimum Risk	300	45	Not Overcrowded
Agricultural Settlement	Hiawa	Minimum Risk	75	88	Overcrowded
Agricultural Settlement	Osamkrom	Minimum Risk	70	104	Overcrowded
Medium Security Prison Nsawam, Eastern Region	Medium Security Prison Nsawam	High Risk	851	2843	Overcrowded
Maximum Security Prison Ankaful, Central Region	Maximum Security Prison Ankaful	Very High Risk	2000	1273	Not Overcrowded

Primary_reason_for_ov ercrowding	Budgetary_allocation_for_Basic_Needs	Shorter_sentence_ below_on eyr	Longer_sentence_ above_on e_yr	Freg_of_ remand	percentage_of_pett y_offenc e	Number_ of_petty	Male	Female
	223,708.50	227			100%	227	227	
high sentence	2,011,996.80	574	895	445	45%	861	1914	
high sentence	933,465.60	266	380	242	25%	222	888	
high sentence	316,411.20	90	109	102	30%	90	301	
	108,273.60	31	52	20	31%	32	103	
large area	387,892.80	111	208	50	30%	111	369	
high sentence	597,081.60	170	312	86	29%	165	568	
large area	172,396.80	49	88	27	28%	46	164	
	163,593.00	34	123	9	20%	33	166	
	2,956.50	3			100%	3	3	
large area	587,358.00	179	237	180	30%	179	596	
	27,594.00	6	22		21%	6	28	
	67,999.50	14	54	1	20%	14	69	
large area	395,185.50	80	309	12	19%	76	401	
	32,521.50	5	28		15%	5	33	
	49,275.00	8	26	16	19%	10	50	
	103,477.50	16	84	5	15%	16	105	
high sentence	320,287.50	83	208	34	25%	81	325	
	94,608.00	11	74	11	11%	11	96	
	451,359.00	54	341	63	12%	55	458	
	74,898.00	9	56	11	13%	10	76	
	81,796.50	10	73		12%	10	83	
	74,898.00	9	67		10%	8	76	
	20,695.50	6	10	5	28%	6		21
	15,768.00	4	5	7	25%	4		16
	9,855.00	3	6	1	30%	3		10
	66,028.50	20	39	8	24%	16		67
	6,898.50	3	2	2	42%	3		7
	8,869.50	3	5	1	33%	3		9
	13,797.00	4	9	1	28%	4		14
	597,213.00	606		14	100%	606	606	
	229,621.50	233			100%	233	233	
	71,941.50	73			100%	73	73	
	211,554.00	230			100%	230	230	
	141,649.20	154			100%	154	154	
	155,446.20	169			100%	169	169	
	74,503.80	81			100%	81	81	
	194,077.80	211			100%	211	211	
	116,814.60	127			100%	127	127	
	41,391.00	45			100%	45	45	
	80,942.40	88			100%	88	88	
	95,659.20	104			100%	104	104	
large area/long sentence	3,268,739.25	851	1789	203	12%	341	2843	
	1,463,631.75	186	1048	39	5%	64	1273	

Appendix II

		Classification of offences	GREATER ACCRA REGION	EASTERN REGION	CENTRAL REGION	WESTERN REGION	ASHANTI REGION	VOLTA REGION	BRONG AHAFI REGION	NORTHERN REGION	UPPER EAST REGION	UPPER WEST REGION	TOTAL	latitude	longitude
	CRIME														
1	STEALING	Non Petty	34	768	238	257	430	211	95	65	65	61	2221	-73.9856	40.72779
2	PETTY THEFT	Petty	34	768	238	257	430	211	95	65	65	61	2221	-74.0045	40.74692
3	UNLAWFUL ENTRY	Petty	19	271	113	60	317	77	35	29	43	25	989	-74.0024	40.7217
4	CONSPIRACY	Petty	16	254	86	138	263	49	58	23	17	3	907	-73.983	40.68962
5	CAUSING DAMAGE	Non Petty	7	170	68	88	175	44	32	15	16	19	634	-73.9888	40.67051
6	CAUSING HARM	Non Petty	4	155	81	56	100	48	69	8	15	11	547	-74.0411	40.71649
7	DEFILEMENT	Non Petty	51	105	32	27	64	51	152	5	4	2	493	-73.9216	40.75691
8	ROBBERY	Non Petty	9	183	23	22	99	27	54	8	6	20	451	-74.072	40.72573
9	TRAFFIC OFFENCES	Petty	1	185	15	19	36	52	40	0	3	7	358	-73.9821	40.75227
10	OTHERS	Non Petty	0	56	19	23	121	15	16	13	9	11	283	-74.0064	40.70437
11	ASSAULT	Non Petty	1	72	33	14	71	32	31	3	13	7	277	-73.9377	40.81807
12	DEFRAUDING	Non Petty	0	125	55	26	16	19	1	12	6	2	262	-73.9195	40.8164
13	POSS NARCOTIC DRUGS	Non Petty	1	69	4	9	49	11	102	2	1	0	248	-73.8974	40.82393
14	FRAUD	Non Petty	0	35	33	16	72	0	70	0	0	0	226	-73.9046	40.7645
15	THREAT OF DEATH	Non Petty	0	31	10	12	41	22	28	6	1	1	152	-73.9098	40.75806
16	ILLEGAL MINING	Non Petty	0	67	14	15	16	0	0	0	32	0	144	-73.9016	40.75753
17	ESCAPING FROM LAWFUL CUSTODY	Non Petty	2	24	15	30	12	11	26	2	2	2	126	-73.9077	40.75776
18	ABETMENT OF CRIME	Non Petty	0	45	6	12	21	8	17	0	6	6	121	-73.9889	40.66238
19	DISHONESTLY RECEIVING	Non Petty	1	29	8	7	20	9	19	4	16	4	117	-73.9757	40.65155
20	UNLAWFUL POSS OF OFFEN WEAPON	Petty	1	16	7	5	24	11	20	4	0	21	109	-73.9161	40.84818
21	ENTERING FOREST RESERVE WITHOUT	Petty	0	0	10	4	4	0	0	7	77	1	103	-74.0424	40.7408
22	ATTEMPT TO COMMIT CRIME	Non Petty	0	43	14	21	0	1	0	3	2	0	84	-73.9221	40.84775
23	ATTEMPTED STOWAY	Non Petty	0	0	0	60	0	0	0	0	0	0	60	-73.9192	40.84963
24	INDECENT ASSAULT	Non Petty	4	6	9	0	0	1	30	0	0	1	51	-74.027	40.74313
25	MURDER	Non Petty	1	14	3	0	0	0	19	4	2	0	43	-73.8996	40.8558
26	OFFENSIVE CONDUCT	Non Petty	0	6	0	5	6	5	17	0	3	0	42	-73.8974	40.82388
27	BEING ON PREMISES FOR UNLAWFUL P	Petty	0	12	3	18	7	0	0	0	2	0	42	-73.9664	40.66876
28	MANSLAUGHTER	Non Petty	0	7	1	1	8	1	20	1	1	0	40	-73.963	40.66366
29	SALE OF UNREGISTERED MEDICINE	Non Petty	0	18	2	0	8	3	6	3	0	0	40	-73.9692	40.68416
30	CONTEMPT OF COURT	Non Petty	0	21	4	1	0	8	2	0	0	0	36	-74.0711	40.72755
31	IMPERSONATION	Non Petty	0	14	0	1	0	1	16	2	0	0	34	-73.9819	40.76916
32	HAVING POSS. OF STOLEN PROPERTY	Non Petty	0	16	5	2	2	6	0	1	1	0	33	-73.9001	40.77542
33	RAPE	Non Petty	3	3	1	0	0	0	19	0	0	0	26	-74.031	40.73736
34	FRAUDULENT BREACH OF TRUST	Non Petty	0	9	4	1	0	5	0	1	3	0	23	-74.0286	40.74097
35	ABDUCTION/KIDNAPPING	Non Petty	0	11	3	0	0	2	0	0	2	0	18	-74.0357	40.73743
36	RESISTING ARREST	Non Petty	0	2	7	0	2	4	0	0	0	0	15	-73.9817	40.78379
37	THREAT OF HARM	Non Petty	0	5	6	0	2	0	0	0	0	0	13	-74.0625	40.73367
38	CHILD STEALING	Non Petty	0	4	0	0	3	0	0	3	0	1	11	-73.8979	40.86659
39	INCEST	Non Petty	0	4	4	2	0	0	0	0	0	0	10	-73.9084	40.81989
40	FOREITURE OF RECOGNAIZANCE	Non Petty	0	4	0	0	0	3	0	0	0	1	8	-73.9375	40.8358
41	CARNAL KNOWLEDGE WITH IMBECILE	Petty	0	3	3	0	0	1	0	0	0	0	7	-73.9454	40.83928
42	HUMAN TRAFFICKING	Non Petty	0	6	0	0	0	0	0	0	0	0	6	-73.9274	40.83206
43	CRUETY TO ANIMAL	Non Petty	0	2	0	0	0	4	0	0	0	0	6	-73.8883	40.82058
44	ISSUE OF FALSE CHEQUE	Non Petty	0	0	4	0	0	2	0	0	0	0	6	-73.9137	40.83579
45	POSSESSION OF FORGED CURRECY	Non Petty	0	2	0	0	0	0	0	0	0	2	4	-73.8931	40.83588
46	FICTITIOUS TRADING	Non Petty	0	1	0	1	0	0	0	0	0	0	2	-73.9357	40.85691

Appendix III

station_id	name	latitude	longitude	region_id	last_reported	booking_date	booking_time	jacket_num1	jacket_type
3326	Clinton St & Ce	40.67434	-74.00194698	71	2021-09-02T00:00:C	40909	0.013356481	22914	A
3591	21 St & 31 Dr	40.7659	-73.930819	71	2021-09-02T00:00:C	40909	0.013356481	22914	A
3756	White St & Moo	40.704508	-73.9351	71	2021-09-02T00:00:C	40909	0.013356481	22914	A
3845	Irving Ave & Ha	40.70108	-73.9179	71	2021-09-02T00:00:C	40909	0.072743056	1024225	A
4296	Steinway St & I	40.778089	-73.899558	71	2021-09-01T00:00:C	40909	0.072743056	1024225	A
4323	20 Ave & 33 St	40.779399	-73.905708	71	2021-09-01T00:00:C	40909	0.088784722	1024226	A
4347	21 St & 4 Ave	40.662584	-73.995554	71	2021-09-01T00:00:C	40909	0.111956019	1024227	A
4352	McDonald Ave	40.651654	-73.981231	71	2021-09-02T00:00:C	40909	0.120277778	1024228	A
4356	Greenwood Ave	40.650739	-73.977739	71	2021-09-02T00:00:C	40909	0.123553241	1008729	A
4360	Caton Ave & Ar	40.649681	-73.967829	71	2021-09-02T00:00:C	40909	0.123553241	1008729	A
4367	Chester Ave & I	40.644367	-73.984276	71	2021-09-01T00:00:C	40909	0.123553241	1008729	A
4398	65 St & 2 Ave	40.640493	-74.02564	71	2021-09-01T00:00:C	40909	0.141111111	1024229	A
3511	Adam Clayton P	40.802535	-73.9532423	71	2021-09-02T00:00:C	40909	0.141111111	1024229	A
3828	Eldert St & Busl	40.68652	-73.91321	71	2021-09-01T00:00:C	40909	0.148298611	535447	A
3830	Halsey St & Eve	40.68858	-73.91227	71	2021-09-02T00:00:C	40909	0.160532407	1024230	A
4377	Dahill Rd & 12	40.646037	-73.980963	71	2021-09-01T00:00:C	40909	0.160532407	1024230	A
3053	Marcy Ave & L	40.6900815	-73.947915	71	2021-09-02T00:00:C	40909	0.160532407	1024230	A
3315	Henry St & Deg	40.6847514	-73.99917254	71	2021-09-02T00:00:C	40909	0.160532407	1024230	A
3999	Adam Clayton P	40.81695971	-73.94229591	71	2021-09-02T00:00:C	40909	0.223969907	1024234	A
437	Macon St & Nos	40.68098339	-73.95004798	71	2021-09-02T00:00:C	40909	0.223969907	1024234	A
530	11 Ave & W 59	40.77149671	-73.99046034	71	2021-09-02T00:00:C	40909	0.223969907	1024234	A
3388	President St & F	40.6828003	-73.99990419	71	2021-09-01T00:00:C	40909	0.223969907	1024234	A
3494	E 115 St & Lexi	40.797911	-73.9423	71	2021-09-02T00:00:C	40909	0.249247685	951640	A
3495	E 114 St & 1 Av	40.7945663	-73.9362541	71	2021-09-02T00:00:C	40909	0.249247685	951640	A
3856	Kingsland Ave & d	40.72577	-73.94173	71	2021-09-02T00:00:C	40909	0.249247685	951640	A
4006	E 147 St & Berg	40.814673	-73.91839	71	2021-09-02T00:00:C	40909	0.257511574	1024235	A
4255	42 Pl & Northern	40.753091	-73.920603	71	2021-09-01T00:00:C	40909	0.28818287	1024236	A

released_date	released_time	arrest_agency	age_at_arrest	age_at_release	days_in_jail	hours	marital_status
40909	0.081585648	Champaign Police	51	51	0		1 Divorced
40909	0.081585648	Champaign Police	51	51	0		1 Divorced
40909	0.081585648	Champaign Police	51	51	0		1 Divorced
40940	0.444895833	Champaign Police	32	32	1		32 Single
40940	0.444895833	Champaign Police	32	32	1		32 Single
40909	0.605729167	University of Illir	20	20	0		12 Single
40909	0.5346875	University of Illir	20	20	0		10 Single
40909	0.566435185	Champaign Police	17	17	0		10 Single
40909	0.885196759	Champaign Police	19	19	0		18 Single
40909	0.885196759	Champaign Police	19	19	0		18 Single
40909	0.885196759	Champaign Police	19	19	0		18 Single
40909	0.62494213	Urbana Police De	21	21	0		11 Single
40909	0.62494213	Urbana Police De	21	21	0		11 Single
40909	0.475497685	Rantoul Police De	30	30	0		7 Significant Other
40909	0.316168981	Champaign Coun	23	23	0		3 Single
40909	0.316168981	Champaign Coun	23	23	0		3 Single
40909	0.316168981	Champaign Coun	23	23	0		3 Single
40909	0.316168981	Champaign Coun	23	23	0		3 Single
40909	0.364131944	Champaign Coun	22	22	0		3 Single
40909	0.364131944	Champaign Coun	22	22	0		3 Single
40909	0.364131944	Champaign Coun	22	22	0		3 Single
40909	0.364131944	Champaign Coun	22	22	0		3 Single
40909	0.372326389	Rantoul Police De	46	46	0		2 Divorced
40909	0.372326389	Rantoul Police De	46	46	0		2 Divorced
40909	0.372326389	Rantoul Police De	46	46	0		2 Divorced
40940	0.572962963	Illinois State Poli	31	31	1		31 Single
40909	0.699814815	Illinois State Poli	25	25	0		9 Single

Appendix III

school	prisoner_type	Offence_category	Offence_category	offense_level	education_status	statute
Graduated from h	Misdemeanor Arr	1	petty	Misdemeanor	High School Graduate	625-5/11-501(
Graduated from h	Misdemeanor Arr	1	petty	Misdemeanor	High School Graduate	625-5/11-709
Graduated from h	Misdemeanor Arr	1	petty	Misdemeanor	High School Graduate	720-5/31-1
Attends non-local	Felony Arraignm	0	non_petty	Felony	Some School	720-5/12-3.2
Attends non-local	Felony Arraignm	0	non_petty	Felony	Some School	720-5/12-4
RER,FRUIT PICK	Misdemeanor Arr	1	petty	Misdemeanor		720-5/31-1
Felony Arraignm		0	non_petty	Felony		720-5/12-4
Completed GED	Traffic Arraignm	1	petty	Misdemeanor	GED	625-5/6-303
READY High Sc	Misdemeanor Arr	1	petty	Misdemeanor	Some School	CITY OV ARI
READY High Sc	Misdemeanor Arr	1	petty	Misdemeanor	Some School	CITY OV ARI
READY High Sc	Misdemeanor Arr	1	petty	Misdemeanor	Some School	CITY OV ARI
Felony Arraignm		0	non_petty	Felony		720-5/10-3
Felony Arraignm		0	non_petty	Felony		720-5/12-2
Attends non-local	Misdemeanor Arr	1	petty	Misdemeanor	Some School	720-5/26-1-A-
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-501(
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-709
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-804(
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-501(
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-709
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/3-708
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-1204
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	
Graduated from h	Traffic Arraignm	1	petty	Misdemeanor	High School Graduate	625-5/11-501(
Non-attender	Misdemeanor Arr	1	petty	Misdemeanor	NOT CLASSIFIED	WARR OUT C
RKER	Felony Arraignm	0	non_petty	Felony		625-5/11-501(

employment_status	city	race	sex	STATE	zip_code	citizenship	marital_status	military	occupation
Employed - Full Time	CHAMPAIGN	White	Male	ILLINOIS	61821	US	Divorced	None	CONSTRUCTION WO
Employed - Full Time	CHAMPAIGN	White	Male	ILLINOIS	61821	US	Divorced	None	CONSTRUCTION WO
Employed - Full Time	CHAMPAIGN	White	Male	ILLINOIS	61821	US	Divorced	None	CONSTRUCTION WO
Employed - Full Time	CHAMPAIGN	Hispanic	Male	ILLINOIS	61820	US	Single	None	UNEMPLOYED
Employed - Full Time	CHAMPAIGN	Hispanic	Male	ILLINOIS	61820	US	Single	None	UNEMPLOYED
Employed - Part Time	CHICAGO	White	Male	ILLINOIS	60655	US	Single	None	LABOR POOLS,IABOI
Unemployed	CHICAGO	White	Male	ILLINOIS	60655	US	Single	None	
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61821	US	Single	None	UNEMPLOYED
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61820	US	Single	None	UNEMPLOYED
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61820	US	Single	None	UNEMPLOYED
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61820	US	Single	None	UNEMPLOYED
Employed - Full Time	URBANA	White	Male	ILLINOIS	61801	US	Single	None	PROFESSIONAL
Employed - Full Time	URBANA	White	Male	ILLINOIS	61801	US	Single	None	PROFESSIONAL
Unemployed	CHAMPAIGN	Black	Female	ILLINOIS	61821	US	Significant Other	None	UNEMPLOYED
Employed - Full Time	CHICAGO	White	Male	ILLINOIS	60642	US	Single	None	SERVICE PERSONNE
Employed - Full Time	CHICAGO	White	Male	ILLINOIS	60642	US	Single	None	SERVICE PERSONNE
Employed - Full Time	CHICAGO	White	Male	ILLINOIS	60642	US	Single	None	SERVICE PERSONNE
Employed - Full Time	CHICAGO	White	Male	ILLINOIS	60642	US	Single	None	SERVICE PERSONNE
Employed - Full Time	FISHERS	White	Male	INDIANA	46037	US	Single	None	MECHANIC(REPAIR I
Employed - Full Time	FISHERS	White	Male	INDIANA	46037	US	Single	None	MECHANIC(REPAIR I
Employed - Full Time	FISHERS	White	Male	INDIANA	46037	US	Single	None	MECHANIC(REPAIR I
Employed - Full Time	FISHERS	White	Male	INDIANA	46037	US	Single	None	MECHANIC(REPAIR I
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61820	US	Divorced	None	UNEMPLOYED
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61820	US	Divorced	None	UNEMPLOYED
Unemployed	CHAMPAIGN	Black	Male	ILLINOIS	61820	US	Divorced	None	UNEMPLOYED
Employed - Full Time	BLOOMINGDALE	Hispanic	Male	ILLINOIS	61701	Mexico	Single	None	FACTORY WORKER
Unemployed	BLOOMINGDALE	Hispanic	Male	ILLINOIS	61701	Mexico	Single	None	CONSTRUCTION WO