KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

EPIDEMIOLOGICAL MODELING OF PROMISCUOUS LIFE STYLE ON UNIVERSITY CAMPUS

By

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Declaration

I hereby declare that this submission is my own work towards the award of the M. Phil degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which had been accepted for the award of any other degree of the university, except where due acknowledgement had been made in the text.

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Dedication

I dedicate this work to God almighty for His grace and mercies for seeing me through to this level and also to my family.

Abstract

This work looks at the mathematical analysis of promiscuous life style on university campus. An epidemiological model depicting the dynamics of campus promiscuous life style as an epidemic and is used to study the existence and how the 'disease' is spread.The promiscuous life style include drug taking, alcoholism, obesity, prostitution and many others.In the work the one considered is prostitution.The terms promiscuous life style and prostitution are used interchangeably . The model used is the SIR model. Three models are considered; promiscuous life style among students, promiscuous life style among male lecturers and one among female students and male lecturers. The basic reproductive numbers are established and analyze in each model. The stability analysis of the disease-free and endemic state reveals unstable disease free and stable endemic state. Graphical result is presented and discussion on them is done. The numerical analysis reveals transmission rate being more sensitive to the model than the recovery and departure rate. Numerical solutions are presented to illustrate the stability analysis using Generalized Euler method.

The model suggests that the admitting and recruitment of new members play a significant role in reduction of campus promiscuous life style problem. Thus, minimizing recruitment of prostitute student and prostitute lecturers reduces the spread of the disease, revealing that basic reproductive numbers are not enough to predict whether or not culture of prostitution will persist on university campus

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Chapter 1

Introduction

Mathematical modeling of topics involving addiction and spread of disease has been carried out in many areas of studies due to its importance. Mathematical modeling can be a predictive tool which will help to determine existence and treatment strategies. In the modeling, one needs to develop a useful model which will give practitioners and academia valuable predictions which can be employed to affect strategy in a positive way. Mathematical models for disease spread and addiction subjects, or more generally epidemics, typically are based on differential equations with in- built a threshold which tells a bahavour. The importance of the threshold is to determine the existence of an epidemic base on the parameter values when exceed the threshold. The promiscuous life style being an epidemic may include, drug taking, alcoholism, obesity, prostitution and many others.Considering prostitution in this work.

Prostitution is the business or practice or act of engaging in sexual relations, especially in a promiscuous way in exchange for money or other things of value. The person involved is called prostitute. Prostitution is said to be the world oldest profession. Prostitution occurs in various forms;

- Street prostitution/worker; is where prostitute wait at the street and solicit customers usually dressed in skimpy provocative clothing.
- Brothels: is establishment specifically dedicated to prostitution.
- Escort; the prostitute is escort to client whether in the house, hotel or rented place.
- Sex tourism; Travel for sexual intercourse or for any sexual activity.
- Virtual sex; Sexual act conveyed by message rather than physical practice.

Others may include; Camp follows, Bar prostitute, Interracial prostitute, Dance hall prostitute, Gimmick prostitute. The cause of prostitute may include; Poverty, underage employment, unhealthy working condition, unemployment, Pollution and corruption in industrial or job centers, immoral traffic in women and children, family cause, marital factors, bad neighborhood, illegitimate motherhood, broken homes, hemophiliacs and peripatetic philanderers, Religion and Cultural factors, Gender base domination, policies favoring legalization, ignorance, lack of high moral. All these causes is on the bases of Demand for victims to be use. People engage in prostitution may end up in;

- STIs and other venereal diseases
- STD's
- High risk of unwanted pregnancy.
- Risk of injury from violent clients.
- Risk of alcohol/drug addiction to deal with the lifestyle.
- Depression/guilt.
- Can no longer be a part of general society.
- Shunning from anyone who realizes her profession or social status.
- Possibly never gaining a proper education.

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The term 'prostitution' looks too harsh and offensive, that why many research work on the term have been re-frame using jargons like 'sex workers', 'Campus chicken' and others.

1.1 Background of the study

In areas on Prostitution includes mathematics works like Sex workers industry as supply and demand system (Davidoff et al 2006). And dynamic of poverty and prostitution in Nigeria, (Oduwole et al, 2013). Base on the work of Aidoo et al on ‘campus drinking’ motivated me to look into campus prostitution. The basic cause of prostitution by student and lecturers may be the demand and supply form. Lecturer may demand sex from student for the supply of marks, money or anything from lecture. While student may demand for marks, money or anything value and in-turn supply sex with the exception of unemployment and illiteracy. The other causes may be those discuss in the introduction. The spread of disease including prostitution on campus has both short and long term negative consequence on campus environment thus, students, lectures, other workers, academic works and public health. Prostitution may cause academic indiscipline. Academic indiscipline corrupts the quality of future leaders.

1.2 Statement of the problem

The spread of disease on campus has both short and long term negative consequence on campus environment thus, students, lectures, other workers, academic works and public health. Academic indiscipline corrupts the quality of future leaders. Research on campus prostitution has being carried out by many researchers in many fields of studies but it has not being analyzed mathematically. This work is to analyze prostitution on campus using mathematical model. The model depict the existence and spread of prostitution as an epidemic disease on university, thus an epidemiological model capturing the dynamics of prostitution on university campus.

1.3 Objectives of the thesis

- To develop mathematical model for prostitution on university campus.
- To use the models to determine the basic reproductive number for the spread of the disease.

- To determine the stability of equilibriums.
- Do sensitivity analysis to study the effects of the model parameters in the solution.

1.4 Methodology

Mathematical model was model with compartmental diagrams, their system of ODE's solved at equilibrium, the basic reproductive number determine, disease-free and endemic equilibrium state determined, stability analysis was carried out. Numerical simulation was carried out using Matlab software and results graph and analyzed .

1.5 Justification

Focusing on the epidemiology of modelling diseases on campus, several mathematicians have tried to model and analyze several diseases including drug abuse and alcoholism using ordinary differential equation since it helps in other fields of studies, policymakers, stakeholders in decision making in dealing with real life problems.But sexual activities which we are terming 'prostitution' in this work has not been considered mathematically. One of the challenges affecting the academic field is prostitution on our campuses of studies.In this situation, it is very vital if we look within the field of ordinary differential equation in modelling the disease.

This thesis provides model epidemiology that can help to analyse any infectious disease effectively. It contributes in the area of academics since we provide method of solving the model by ordinary differential equation. It also enables researchers and students develop interest in modelling any infectious disease or real life phenomena by ordinary differential equation.

1.6 Organization of the thesis

This thesis comprises of five chapters. Chapter one reviews the introduction, background of the study, statement of the problem, the objectives of the thesis, the methodology applied in the study, as well as the justification and the organization of the thesis. Chapter two consists of the review of relevant literature research work related to the thesis. In chapter three,we examines the methodology used. formulate SIR model of the disease transmission. The methods of solution, equilibrium points or steady states, the reproductive number were determined and stability analysis was carried out Chapter four comprise of numerical analysis of the model. Chapter five, the final chapter contains the conclusions and the recommendations of the thesis.

Chapter 2

Literature Review

2.1 Introduction

In this chapter we reviewed the work of other researchers related to the topic.

2.2 Abstracts Relevant to this thesis

Most mathematical modelling on Spread of diseases on campus has been looked at by researcher such as drug taking, alcoholism,smoking,etc.Another infectious disease 'prostitution' though has been look at generally in various field including the use of mathematical model, and on university campus has been considered but not the use of mathematical model.

work like, 'A Mathematical Model on the Dynamics of Poverty and Prostitution in Nigeria' by Oduwole and Shehu (2013).They proposed a compartmental mathematical model that tracks the dynamic of poverty and prostitution in Nigeria and introduce a non-violent compartment that focuses on rehabilitating both male and female prostitutes.The stability of the system was analyze for the existence of the prostitution free equilibrium and established that there exist a prostitution free equilibrium point that is locally asymptotically stable when the reproduction number $R_0 < 1$ and unstable when $R_0 > 1$. It shows that the dynamics of prostitution is relates to many forms of poverty and crime. Poverty eradication and control should be the focus of good governance in developing countries base on their the model.Hence high rate of government interventions will reduce to the barest minimum the number of members in both poverty and prostitution class.

'Prostitution on Demand' Legalizing the Buyers as Sexual Consumers Raymond (2004) The article looks at the demand.Its Meaning,The myths that rationalize why men buy women in prostitution, consequences of legalized prostitution on the demand,the invisible men who constitute the demand,background of buyers including age,education,and occupation of buyers, buyers, demands,programs and policies that address the demand and Qualitative information on the buyers contained in two studies conducted by the Coalition Against Trafficking in Women (CATW) -as well as best practices that address the gender of demand.He did not contend in the article that it is only male demand for the sex of prostitution that promotes trafficking, prostitution, and the sex industry.But do contend that male demand is a primary factor in the expansion of the sex industry worldwide and sustains commercial sexual exploitation, and that the buyer has largely escaped examination, analysis, censure, and penalty for his actions.

Mathematical Modeling of the Sex Worker Industry as a Supply and Demand System.Davidoff et al. (2006) construct two mathematical models to explore the dynamics of the sex industry: one for the males who provide demand and another for the females who provide the supply and qualitative analysis on these models separately. In the male model, holding all parameters constant the active customer free equilibrium,C_aFE, and the basic reproductive number Rm where determine. And that equilibrium exists for $Rm > 1$. For the female model,all parameters were hold constant and determined the prostitute free equilibrium, PFE, and the basic reproductive number Rf. for the coupled model they observed that, as a function of demand, appears to have a greater effect on the steady states of the female system, indicating the importance of decreasing the male demand in order to decrease enough to change Rf .Through the explore of the coupled system numerically that the male dynamics are not very sensitive to the changes in the female population. Through which explanations were made as to why the current system of arrest and detainment of the female does little to control the sex worker population but also, if the efforts of legal enforcement focus on making male arrests, it is possible to significantly reduce the number of women in prostitution.

'A mathematical analysis of alcoholism'. Bhunu (2012) A deterministic mathematical model for the spread of alcoholism was design and analysed to gain insights into this growing health and social problem. The reproduction number and equilibria states of the model were determined and their local asymptotic stabilities found. Analysis of the R_0 have shown conditions under which encouraging and supporting moderate drinkers to quit alcohol consumption is more effective in the control of alcoholism than supporting and encouraging alcoholics to quit and vice-versa. Numerical simulations show that targeting moderate drinkers by encouraging and supporting them to quit alcohol consumption will in the long run be more effective in dealing with the spread of alcoholism than singly targeting alcoholics only.Numerically it was observe that encouraging and supporting all alcohol consumers to quit drinking will be the best strategy.

Hardit (2012) on 'Predicting sexual aggression among college men'. The purpose of the study was to examine various components of the confluence model (Malamuth et al., 1991) of sexual aggression with a population of contemporary college men. Where the confluence model compose of two intercorrelated pathways: Hostile masculinity; composed of negative attitudes and beliefs towards women, and impersonal sex; characterized by engaging in sexual relationships that lack emotional closeness. The study investigated various components of the confluence model as predictors of sexual aggression among college men. The potential influence of membership in male socialization peer groups, such as fraternities and athletic teams, and their impact on sexual aggression was examined. Again, the study aimed to investigate the effects of modern forms of sexualized media on various predictors in the confluence model. Hierarchical regression analyses revealed partial support for components of the confluence model. Significant mediating and moderating effects of confluence model variables were present. Contrary to hypotheses, the level of consumption of sexualized media did not moderate any of the pathways to sexual aggression. Membership in a fraternity was associated with higher levels of reported sexual aggression. The finding highlight the importance of certain male peer group membership as one factor in sexual aggression among college men.

Ham and Hope (2013) On clinical psychology review on 'College students and problematic drinking'.The review was to examine the primary psychosocial factors that predict problem drinking in college students. Variables examined included demographic variables, personality, drinking history, alcohol expectancies, drinking motives, stress and coping, activity involvement, and peer and family influence. The study indicated that the variables associated with college drinking seem to vary at levels dealing with one's personality and coping mechanisms,one's thought processes about drinking, and the environment. It seems that expectancies and drinking motives may serve as explanations for the pathways from certain personality types (i.e., sensation seeking and neurotic) to problem drinking in the college setting. Factors that predicted future drinking problems after college were also examined.It seems that interventions and prevention programs would need to reach college students at all levels; the environment, individual personality traits, and cognitive processes. Overall, the research indicated that there were two subsets of college students that are at risk for problem drinking. The first subset was that of the sensation seeking personality type, consisting mainly of students who drank for social or enjoyment reasons. The second subset was that of the neurotic personality type, consisting mainly of students who drank for coping or conformity reasons. Individuals in this smaller subset appeared more likely to respond to distress by drinking, experience negative affect, and be female students.

Tura et al. (2012)'Risky sexual behaviour and predisposing factors among students of Jimma university, Ethiopia. It was to assess the pattern of risky sexual behaviours and predisposing factors among Jimma University students. Qualitative data were analyzed by thematic areas. It was observed that, among the respondents, 26.9 percent ever had sexual intercourse. 75.6 percent, started sexual intercourse during secondary school, 51.0 percent had sex in the last 12 months and 28.3 percent had multiple sexual partners. The predisposing factors identified include; Lack of parental control, substance use, peer pressure, campus and outside environment. they conclude that, risky sexual behaviour such as having multiple sexual partner and sexual practice exists. The university and local health bodies should work together to address the identified risky behaviors with particular focus on behaviour change communication.

J'odara et al. (2008)'Modeling dynamics of infant obesity in the region of Valencia, Spain'. They present a finite - time 3 -5 years old childhood obesity model to study the evolution of obesity in the next years in the Spanish region of Valencia.It was seen statistically that sociocultural characteristics determine the nutritional habits and the unhealthy ones such as high frequency of consumption of bakery, fried meals and soft drinks (BFS)) which are prevalent factors in childhood obesity. The analysis allows them to consider obesity as a disease of social transmission caused by high frequency consumption of BFS and to build a mathematical model of epidemiological type to study the childhood obesity evolution. The parameters of the model using data from surveys related to obesity in the Spanish region of Valencia are computed adjusting the model to real data of the years 1999 and 2002.Best estimated values only for the parameters and κ fitting the model in order to minimize the mean square error between the model and the real data in the year 2002.Based on the sensitivity analysis, they find that the parameters L and κ are the most important in the proposed model. The transmission rate due to social pressure on BFS consumption and the frequency of BFS consumption measured by L and S should be targeted. It was noted that the models works well over a short time span, since it is difficult to believe that parameters remain constant for long time periods and it is more suitable to use varying parameters that can be modeled through time-dependent parameters. The simulation shows an increasing trend of childhood obesity in the following years.

'Indecent Dressing on Campuses of Higher Institutions of Learning in Nigeria'.Omede (2011)The paper examined the causes and effects of indecent dressing and suggested solutions that could reduce the rate of spread of this immoral act.Thus looked at reason behind indecent dressing pattern that is common among female students of higher institutions of learning in Nigeria particularly, such as poor parenting, peer pressure, wrong use of the Internet, fading values as well as demonic influence among others. The negative consequences of dressing indecently were identified to include rape, prostitution, HIV/AIDS and other venereal disease infection as well as armed robbery, lying and poor school grades. Recommendations put forward included that parents be good moral exemplars to their children, give them attention and regulate the films they watch at homes, the mass media must promote good moral values, religious leaders must preach against, counsel and deliver those under demonic influence, as well as the introduction of college or university uniforms for students.

Busenberg et al. (1994) A model which depict the spread of HIV/AIDS in the community.The disease spread was mainly due to the sexual interaction between a core group of female prostitutes and young unmarried males.Threshold parameters were obtained that determine persistence of endemic proportions, persistence of total population, and the persistence of infective population given the extinction of endemic proportions in a population tending to infinity. Conditions were given for the existence of multiple endemic equilibria as well as the existence of multiple stable equilibria with separatrix.Their asymptotic behavior and biological significance were discussed.Numerical examples were provided for some particular cases of interest.

‘Campus drinking: an epidemiological model’.Manthey et al. (2009) The work is on the dynamics of campus drinking which have not been analyzed using mathematical models. An epidemiological model capturing the dynamics of campus drinking was used to study how the ‘disease’ of drinking is spread on campus. The model suggests that the reproductive numbers are not sufficient to predict whether drinking behavior will persist on campus and that the pattern of recruiting new members plays a significant role in the reduction of campus alcohol problems. In the model, they assume that problem drinkers can recruit both non-drinkers and social drinkers. This allows to transition to the problem drinking state both directly and via progression through social drinking. In the limit case, they modified this assumption and allowed problem drinkers to only recruit social drinkers. And that, non-drinkers may transit to the problem drinking class only after progressing through social drinking. As a result, the dynamics of campus drinking are significantly impacted. Surprisingly, in the limiting case, even with a large reproductive number R1 , the proportion of both social and problems drinkers is reduced.This suggests that one possible strategy for reducing drinking problems on campus is to modify the recruitment patterns They observed that , campus alcohol abuse may be reduced by minimizing the ability of problem drinkers to directly recruit non-drinkers.

‘Prostitution: Causes and Solutions’.Hughes (2004) He considered prostitution and sex trafficking.saying the two are inextricably linked.According to him, sex trafficking is the process that delivers victims into prostitution. It includes the recruitment,harboring, movement, and methods by which victims are compelled to stay in prostitution, whether by violence, coercion, threat, debt, or cultural manipulation. Prostitution and sex trafficking are based on a balance between the supply of available victims and the demand for victims to provide the sex acts. Prostitution and trafficking begin with the demand for victims to be used in prostitution. It begins when men go in search of sex that can be purchased. In countries where prostitution is illegal, it begins when pimps place orders with their criminal networks for women and children.He talks about another solution to prostitution as stopping of the demand instead of legalization. He say,instead of legalization, another solution to the problem of prostitution and sex trafficking is confronting the demand for prostitution. Instead of only warning women against recruiters, stop the recruiters. Instead of accommodating the demand, stop it. The components that make-up the demand:The men who buy commercial sex acts, the exploiters who make up the sex industry, the states that are destination countries, and the culture that tolerates or promotes sexual exploitation.He believe that only by going to the root cause of prostitution and trafficking, which are the factors that make up the demand.To end the sexual exploitation and abuse of women and children through prostitution and trafficking, governments, NGO_S, and religious communities to focus on reducing the demand for victims of sex trafficking and prostitution. All the components of the demand need to be penalized - the men who purchase sex acts, the exploiters - the traffickers and pimps who profit from the sale of women and children for sex, the states that fund deceptive messages and act as pimp, and the culture that lies about the nature of prostitution. We could greatly reduce the number of victims, if the demand for them was penalized. If there were no men seeking to buy sex acts, no women and children would be bought and sold. If there were no brothels waiting for victims, no victims would be recruited. If there were no states that profited from the sex trade, there would be no regulations that facilitated the flow of women from poor towns to wealthier sex industry centers. If there were no false messages about prostitution, no women or girls would be deceived into thinking prostitution is a glamorous or legitimate job.

Gani (1965) considered the differential-difference equations of the SIR model with constant population size and gives the partial differential equation which the associated probability generating function satisfies and outlines a mathematical method for solving it. However, the mathematics involved is so complicated that it limits its success in the SIR model varying the population sizes of at most 3 individuals.

'Sex on campus' .Sachdev (2000). A Preliminary study of knowledge attitudes and behaviour of university student in Delhi, India. The study provides baseline information on the sexual attitudes and behaviour of young students from two universities in Delhi. The findings by and large confirm the general trend favoring more liberal sexual attitudes. The study gives some evidence that female respondents are beginning to cast off traditional moral restraints and experience their own sexuality. However, significant gender differences in sexual attitudes and behaviour still persist.The study shows that while attitudes are changing, behaviour lags behind.He realise that it is possible that more Indian college women are likely to engage in this sexual behaviour as cultural forces give them more freedom to express their sexuality.sexual behaviour of Indian students 103the data show that there is a lack of sex knowledge among the respondents. Also, most of them relied less for information on their parents and more on their peers.Studies have shown that attitudes and behaviour of adolescents, especially daughters, are significantly influenced by maternal attitudes in a family where there is open sexual communication female students were more ignorant than males in this sample about sexuality and had beliefs in sexual myths. One caution is in order. The findings of the study are based on a convenience sample of male and female students from urban universities and should not be generalized to young people or college students in the general population.

Andersson (2013). 'epidemic on a configuration model network. They study Susceptible-Infectious-Recovered(SIR) epidemics on configuration model networks, for which they look at a closed population without births, deaths and migration. On that population they look at an SIR epidemic, which divides the population into three different states: susceptible, infectious and recovered. How disease spreads through the population depends strongly on the relations between infectious and susceptible individuals. By constructing a configuration model network it was possible for them to investigate when the epidemic may become large and when it will stay small with probability one and how the distribution of the infectious period affects the outbreak. They answered these questions by using generating functions and percolation theory. They observed that the early stages of an epidemic outbreak can be approximated by a branching process, also this approximation is possible until approximately the $\sqrt{nth}$ infection in a population that consists of n individuals. They also show that an epidemic outbreak is possible when the transmission probability is above the epidemic threshold. They concluded that the transmission of the disease depend on the infectious periods, if the infectious periods are fixed for all individuals the transmission is independent and identically distributed whereas if the infectious periods are random this is not the case. If the infectious periods are random the extinction probability is smaller when we assume that the transmission is independent than when we do not.

Weiss (2013) 'the model and the Foundations of Public Health'. In their work, they introduced and analysed the most fundamental transmission model for a directly transmitted infectious disease. The model consists of a system of three coupled non-linear ordinary differential equations which does not hold a formula solution. Down the way they illustrated how the model helps to lay a theoretical basis for public health interventions and how several cornerstones of public health required such a model to illuminate. They apply their compartment models to study disease transmission like the number of laboratory confirmed flu cases in the US during 2009-2010 H1N1 pandemic. They stated that if all the assumptions of the SIR model held for the outbreak, it would imply there would be only one peak. They also observed that the US experienced only one peak every year expect during the pandemic years 1918, 1968, 2009, where is experienced two or more waves. They also used comparatively extensions of the SIR model to reveal five plausible mechanisms, each of which could have generated the two peaks during 2009, both quantitatively and qualitatively. The first two mechanisms capture changes in virus transmission and behavioural changes. The third mechanism involves population heterogeneity where each wave spreads through one sub-population. The fourth mechanism is virus mutation which causes delayed susceptibility of individuals, and the fifth mechanism is waning immunity. They used the models to inspect the effects of border control at the beginning of the epidemic and the timing of any amount of available vaccinations. They also 16 use the models to try to understand why China had only one peak and the US had two peaks.

Hung and Takeuchi (2011) applied SIR, SIS, SEIR and SEI models of epidemiological dynamics with time delays and a general incidence rate. The work obtained new Lyapunov function which was used to shown the global asymptotic stability of the equilibria.

'Estimating reproductive numbers of a campus drinking model'.Aidoo et al. (2009),Lecture Delivered at Fifth International Conference of Applied Mathematics and Computing (Plovdiv, Bulgaria, August 12 - 18, 2008).Reproductive numbers are central to the epidemiological dynamicsof any disease. However, estimating reproductive numbers have not been the explicit goal of college drinking researchers, since most of their research are not model driven. An epidemiological model capturing the dynamics of campus drinking is used to study how the''disease' of drinking is spread on campus. An optimization technique using known bounds for each parameter is used to estimate the reproductive numbers associated with campus drinking. A theorem establishing the conditions under which an endemic steady state exists is proposed and proved. They established conditions under which an endemic equilibrium of the 'disease' of drinking can exist on a college campus. In addition, they estimated the reproductive numbers associated with campus drinking and are hopeful that this will lead to a better understanding of the dynamics of campus drinking and more effective intervention.

Ichwanny (2007) paper delivered at 4^th International Conference on Reproductive Health and Social Sciences Research. on 'Factors Influencing Adolescent Sexual Behavior in Indonesia 2007'. The study aims is to examine the influence of sex education, role of significant persons, and socio - demographic variables on 'adolescent' sexual behaviour in Indonesia. The study was based on an analysis of data collected at the 2007 Indonesian Young Adult Reproductive Health Survey (IYARHS), conducted by the Central Board of Statistics, National Family Planning Coordinating Board, Ministry of Health and Macro International, the USA. The 2007 IYARHS was conducted in all provinces of Indonesia as a part of the Indonesian Demographic and Health Survey (IDHS). The study sample comprised 19,311 never married male and female adolescent from all the thirty - three provinces of Indonesia. Fifty - six percent of the sample consists of males and 44 percent females. Sixty - five percent of the survey respondents are aged 15 - 19 years and 35 percent aged 20 - 24 years. These are the same proportion as in the general unmarried population aged 15 - 24 years. Female respondents are more likely to live in urban areas (56 percent), while male respondents are more likely to live in rural areas . Unmarried women are more likely to live in urban areas compared to men. The conceptual framework of the study is provided by the Reasoned Action Theory proposed by Ajzen and Fishbein (1980). The results of bivariate and multivariate statistical analysis reveal that pressure from significant persons is the most important contributor to adolescent sexual behaviour. The study also finds that male and older adolescents are more likely to undertake sexual behaviour compared to female and younger adolescent. Sex education is the least important contributor to adolescent sexual behaviour. The results of the discussion support the hypotheses which state that; adolescents aged between 20 - 24 years are more likely to undertake sexual behaviour than those aged between 15 - 19 years old, that male adolescents are more likely to engage in sexual behaviour than female adolescent, and that adolescents who experience pressure from their referents are more likely to engage in sexual behaviour. Finally, although the analysis apparently shows that a higher level of sex education is associated with sexual behaviour, it does not necessarily mean that sex education by itself encourages sexual behaviour among the adolescent.

'Association Between Knowledge, Attitudes and Sexual Practices Among Unmarried Indonesian Young Adults' A Study From Indonesian Young Adults Reproductive Health Survey (Iyarhs) Kusumastuti (2007).The article analyzes knowledge and attitudes of sexual reproductive health (SRH) influencing the unmarried young adult's sexual practices. A secondary data analysis selected variables in knowledge, attitudes and sexual experiences of unmarried Indonesian young adults aged 20 - 24 using data from Indonesian Young Adult Reproductive Health Survey (IYARHS) 2007. The multinomial logistic regression model was used to test the significant differences and predict probability of variables. The finding indicates that knowledge and attitudes have significantly effect on unmarried Indonesian young adult's premarital safe sex. Thus, it is found that knowledge of SRH and positive attitudes towards practicing premarital sex controlling social -demographic factors, namely, education, resident and gender. The result of the study finds the important role of knowledge and attitudes towards sexual practices. It is needed some efforts to increase unmarried Indonesian young adult's knowledge and to shape a positive attitudes towards safe premarital sex. Thus, an appropriate program should be applied to overcome premarital sex issues among young people, namely, unwanted pregnancies, abortions, and sexually transmitted infections (STI) including HIV/AIDS.

The phenomenon of student prostitutes 'Campus Chicken' in some universities in Semarang,Setyatama et al. (2007) , they work was student prostitutes or popularly called in Java as 'campus chicken', ascribed to a university student who sells sex. Unlike common sex workers who sell sex in brothel, campus chicken use special ways to find their clients such as through peers, taxi drivers, etc.They said anonymity is so crucial to protect their identity. The label of university students increases their selling points to be middle or high class prostitutes. The study aims to explore their experiences and behavior including safe sex behaviour. It was a qualitative study using symbolic interaction theory. Six campus chickens participated in this study by using in-depth interview. The result shows that most campus chickens have experienced in sexual intercourse since they were in high school. They were an attractive, friendly and good looking person that usually have part-time job as sales promotion girls of cigarette or automobile products. There were no certain styles of clothing and deportment when they were in campus. Many campus chickens take up prostitution not only because they need enough money for a decent living but also this job to be tolerable because they choose high social status of customers like businessmen, policemen or army and so forth.

Chapter 3

Methodology

3.1 The Model

Spread of diseases on campus has been looked at by researcher such as campus drinking behavior by student on campus by Aidoo et al. This work is on the spread of prostitution as a disease on university campus. It depicts prostitution between students and another one between male lecturers and the combination of the two. Mathematical model on Prostitution on University campus is modeled with compartmental diagrams, their system of ODE's solved at equilibrium, the basic reproductive number and the endemic equilibrium state determined.

3.2 Assumptions

- Constant population size.
- Non prostitute includes never and recovered admitted.
- Recovered can only relapse.
- The rate at which the disease is acquire is proportional to the product of susceptible and infective present
- Transmission is between students, among male lecturers and between male lecturer and female student,
- The effects of breaks and vacations are not considered.
- The rate at which female student and male lecturers are admitted and recruited in the university is proportional to the size of the female students and male lecturers population.

- The rate which susceptible leaves the campus is proportional to group/class of female students and male lecturers population

3.3 Model on student prostitution

Non prostitute students (S) are the susceptible group, thus the students admitted to the school population without the 'disease'. Prostitute students (P) are those whose sexual activities/habits and associated behaviour have negative consequence on others. Recovered student (R) is students who has stopped illegal sex (minimum of 12months).

In this model, αN the number of students admitted into the system every academic year,hence α,the entering and departure rate from campus environment.β is the transmission rate ,γ rate of recovery from prostitution, κ the relapse rate from recovered class to prostitution, σ is the rate at which prostitute are recruited fresh into campus. A student joins the campus as a susceptible or prostitute. And leave in any of the three state. It is considered that individuals admitted as students within the system (campus) at rate $\alpha(S + P + R)$ are automatically 'at risk' for becoming prostitute. The student exits the system naturally out of each state at rates αS,$(\alpha+\sigma)P$, and αR. The model refers to the assumption that students within each compartment are similar with regards to their behaviours.The transition to a lower state is assumed to be a recovery.

3.4 The compartmental diagram and it systems of ordinary differential equations

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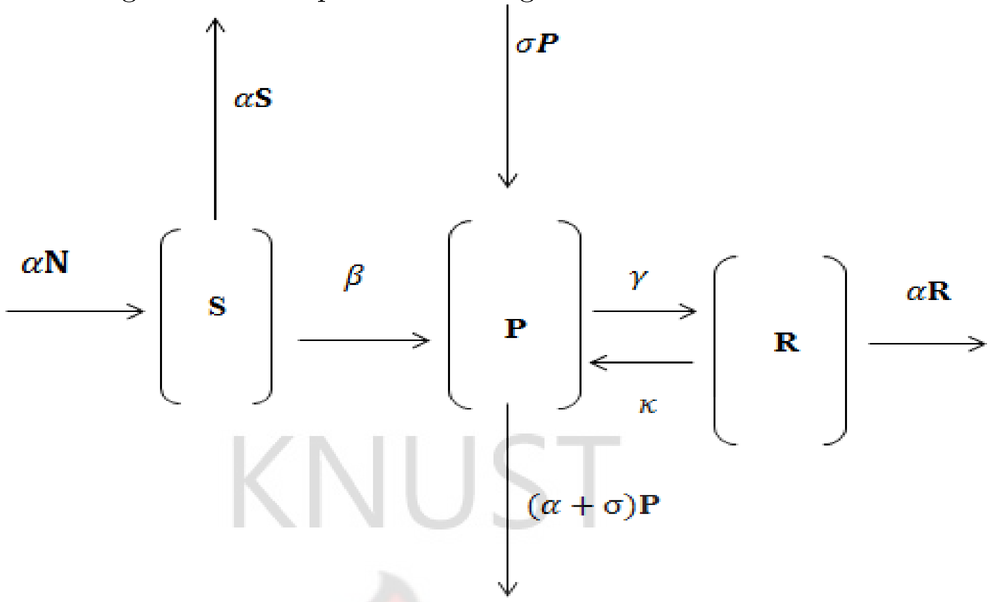
Figure 3.1: Compartmental diagram for students



$$\frac{dS}{dt} = \alpha N - \frac{\beta SP}{N} - \alpha S$$
$$\frac{dP}{dt} = \sigma P + \frac{\beta SP}{N} + \frac{\kappa PR}{N} - \gamma P - (\alpha+\sigma)P \quad 3.1$$
$$\frac{dR}{dt} = \gamma P - \frac{\kappa PR}{N} - \alpha R$$
$$N = S + P + R$$

Rescaling equation 1 by

$s = \frac{S}{N}, p = \frac{P}{N}$ and $r = \frac{R}{N}$

We obtain

$$\frac{ds}{dt} = \alpha - \beta sp - \alpha s$$
$$\frac{dp}{dt} = \sigma p + \beta sp + \kappa pr - \gamma p - (\alpha+\sigma)p \quad 3.2$$
$$\frac{dr}{dt} = \gamma p - \kappa pr - \alpha r$$

s + p + r = 1

At equilibrium , we obtain;

$(s^*, p^*, r^*) = (1, 0, 0)$ and

$(s^*, p^*, r^*) = (x, y, z)$.

where;

$x = \frac{\alpha}{\alpha+\beta p}$

$y = \frac{\sqrt{\beta^2(\gamma^2+\kappa^2+\alpha^2+2\alpha\gamma+2\alpha\kappa-2\gamma\kappa)+\kappa^2(\alpha^2-2\alpha\beta)-2\alpha\gamma\beta\kappa-2\alpha^2\beta\kappa}}{2\beta\kappa}$

$z = \frac{\gamma p}{\alpha+\kappa p}$

3.5 Disease-free equilibrium state

$$J(s,p,r) = \begin{bmatrix} -\beta p - \alpha & -\beta s & 0 \\ \beta p & \beta s + \kappa r - \gamma - \alpha & \kappa p \\ 0 & \gamma - \kappa r & -\kappa p - \alpha \end{bmatrix}$$

$$J(1,0,0) = \begin{bmatrix} -\alpha & -\beta & 0 \\ 0 & \beta - \gamma - \alpha & 0 \\ 0 & \gamma & -\alpha \end{bmatrix}$$

We calculate the basic reproductive number R_0.

Using Hefferman etal (2005).R_0 is the dominant eigenvalue of the matrix.

$G = F_i V_i^- 1$, where;

$$F = \begin{bmatrix} 0 & -\beta & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, V = \begin{bmatrix} \alpha & 0 & 0 \\ 0 & -\beta + \gamma + \alpha & 0 \\ 0 & -\gamma & \alpha \end{bmatrix} \text{ and } G = \begin{bmatrix} 0 & \frac{\beta}{\alpha+\gamma-\beta} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$R_0 = \frac{\beta}{\alpha+\gamma-\beta}$

3.6 Local stability analysis

From

$R_0 = \frac{\beta}{\alpha+\gamma-\beta}$

For unstable disease-free;

$R_0 = \frac{\beta}{\alpha+\gamma-\beta}$.

This means

$R_0 = \frac{\beta}{\alpha+\gamma-\beta} > 1$

$\Rightarrow \frac{\beta}{\alpha+\gamma-\beta} > 1$

$\Rightarrow \beta > \frac{\alpha+\gamma}{2}$.

By the relation of our R_0, The disease will exist if $\beta > \frac{\alpha+\gamma}{2}$.

The disease - free state is stable when $R_0 < 1$, meaning the disease prostitution will die out.

For stable disease - free

$R_0 = \frac{\beta}{\alpha+\gamma-\beta} < 1$

$\Rightarrow \frac{\beta}{\alpha+\gamma-\beta} < 1$

$\Rightarrow \beta < \frac{\alpha+\gamma}{2}$

From the Relation of R_0 obtained, It means that, the transmission rate β relative to the recovery rate γ and departure rate α has a role in determining whether or not the disease prostitution on university campus by student exist.

From the jacobian matrix

$$J(s,p,r) = \begin{bmatrix} -\beta p - \alpha & -\beta s & 0 \\ \beta p & \beta s + \kappa r - \gamma - \alpha & \kappa p \\ 0 & \gamma - \kappa r & -\kappa p - \alpha \end{bmatrix}$$

At disease-free

$$J(1,0,0) = \begin{bmatrix} -\alpha & -\beta & 0 \\ 0 & \beta - \gamma - \alpha & 0 \\ 0 & \gamma & -\alpha \end{bmatrix}$$

Calculating for the eigenvalues;

$$J(1,0,0) = \begin{bmatrix} -\alpha & -\beta & 0 \\ 0 & \beta-\gamma-\alpha & 0 \\ 0 & \gamma & -\alpha \end{bmatrix} = 0$$

We have;

$\lambda_1 = -\alpha$

$\lambda_2 = -\gamma$

$\lambda_3 = \beta - \alpha - \gamma$

From this we can say that the three eigenvalues are negatives $(2\beta > \alpha+\gamma)$.Hence the disease-free equilibrium point at the student model is asymptotically unstable.

3.7 Endemic equilibrium state

$(s^*, p^*, r^*) = (x, y, z)$

where;

$x = \frac{\alpha}{\alpha+\beta p}, y = \frac{\sqrt{\beta^2(\gamma^2+\kappa^2+\alpha^2+2\alpha\gamma+2\alpha\kappa-2\gamma\kappa)+\kappa^2(\alpha^2-2\alpha\beta)-2\alpha\gamma\beta\kappa-2\alpha^2\beta\kappa}}{2\beta\kappa}$

$z = \frac{\gamma p}{\alpha+\kappa p}$

Its Jacobian matrix is

$$J(s,p,r) = \begin{bmatrix} -\beta p-\alpha & -\beta s & 0 \\ \beta p & \beta s+\kappa r-\gamma-\alpha & \kappa p \\ 0 & \gamma-\kappa r & -\kappa p-\alpha \end{bmatrix}$$

From the student model matrix

$$J(s,p,r) = \begin{bmatrix} -\beta p-\alpha & -\beta s & 0 \\ \beta p & \beta s+\kappa r-\gamma-\alpha & \kappa p \\ 0 & \gamma-\kappa r & -\kappa p-\alpha \end{bmatrix}$$

solving for the eigenvalues,$\lambda_{1,2}\,_{,3}$

We obtained the characteristic equation;

$\lambda^3 - x\lambda^2 - y\lambda + z = 0$

Where;

$x = (-\beta p - \alpha + \beta s + \kappa r - \gamma - \alpha - \kappa p - \alpha)$

$y = -(\beta s)(\beta p) - (-\beta p - \alpha)(\beta s + \kappa r - \gamma - \alpha) - (-\beta p - \alpha)(-\kappa p - \alpha) - (\beta s + \kappa r - \gamma - \alpha)(-\kappa p - \alpha) - (\kappa p)(\gamma - \kappa r)$

$z = (-\beta p - \alpha)(\beta s + \kappa r - \alpha - \gamma)(-\kappa p - \alpha) - (-\beta p - \alpha)(\kappa p)(\gamma - \kappa r) - (-\beta s)(\beta p)(-\kappa p - \alpha) d = z - y$

$\lambda_1 = -z$

$\Rightarrow \lambda^2 - x\lambda + d = 0$

from this;

Trace(T)=x and Determinant(D)=d

$\Rightarrow \lambda_{2,3} = \frac{T \pm \sqrt{T^2 - 4D}}{2}$

From the λ values, it reveals that $\lambda_1 = -z$

$\Rightarrow \lambda_1 < 0$ is stable and $\lambda_{2,3} = \frac{T \pm \sqrt{T^2 - 4D}}{2}$

$T < 0, D > 0$

$\Rightarrow T^2 - 4D < 0$ Hence λ_2, λ_3 have negative real part by Trace -determinant plane the system is stable. Therefore λ_1, λ_2 and λ_3 Having negative signs means the system is stable at the endemic state. Thus the disease prostitution is asymptotically stable indicating that it exist among the students.

3.8 A model on male lecturer prostitution

In this model ω the entering and departure rate from campus environment.μ is the transmission rate , ϵ rates of recovery from prostitution, π the relapse rate from recovered class to prostitution, η is the rate at which prostitute are recruited fresh into campus.

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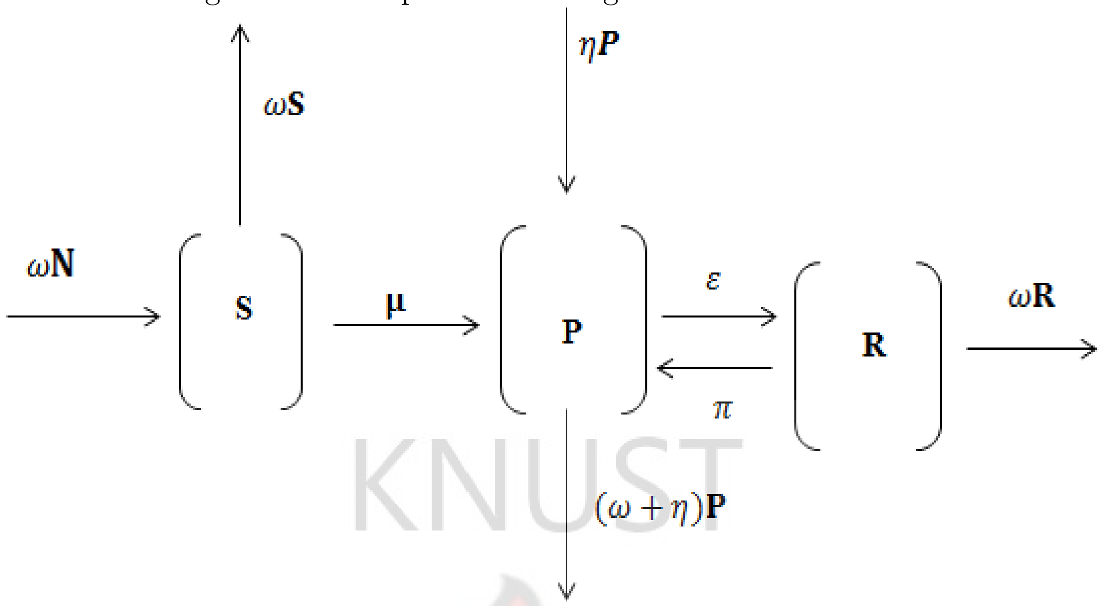
Figure 3.2: Compartmental diagram for male lecturers



The system of ODE's are;

$\frac{dS}{dt} = \omega N - \frac{\mu SP}{N} - \omega S$

$\frac{dP}{dt} = \eta P + \frac{\mu SP}{N} + \frac{\pi PR}{N} - \epsilon P - (\omega + \eta)P$

$\frac{dR}{dt} = \epsilon P - \frac{\pi PR}{N} - \omega R$

$N = S + P + R$

Rescaling equation 3.2.1 by

$s = \frac{S}{N}, p = \frac{P}{N}$ and $r = \frac{R}{N}$

We obtain

$\frac{ds}{dt} = \omega - \mu sp - \mu s$

$\frac{dp}{dt} = \mu sp + \pi pr - \epsilon p - \omega p$ 3.2.2

$\frac{dr}{dt} = \epsilon p - \pi pr - \omega r$

s + p + r = 1

At equilibrium , we obtain;

$(s^*, p^*, r^*) = (1, 0, 0)$ and

$(s^*, p^*, r^*) = (a, b, c)$

where;

$a = \frac{\omega}{\omega+\mu p}$

$b = \frac{\sqrt{\mu^2(\epsilon^2+\pi^2+\omega^2+2\omega\epsilon+2\omega\pi-2\epsilon\pi)+\pi^2(\omega^2-2\omega\mu)-2\omega\epsilon\mu\pi-2\omega^2\mu\pi}}{2\mu\pi}$,

$c = \frac{\epsilon p}{\omega+\pi p}$

3.9 Disease-free equilibrium state

The disease - free equilibrium;

$(s^*, p^*, r^*) = (1, 0, 0)$

The basic reproductive number R_0;

$R_0 = \frac{\mu}{\omega+\epsilon-\mu}$

3.10 Local stability analysis

From

$R_0 = \frac{\mu}{\epsilon+\omega\omega-\mu}$

This means

$R_0 = \frac{\beta}{\alpha+\gamma-\beta} > 1$

$\Rightarrow \frac{\mu}{\epsilon+\omega\omega-\mu} > 1$

$\Rightarrow \mu\mu > \frac{\epsilon+\omega}{2}$.

By this, the disease will exist if $\mu > \frac{\epsilon+\omega}{2}$.

The disease - free state for lecturer model is stable when $R_0 < 1$, meaning the disease prostitution will die out.

For stable disease - free

$\Rightarrow \frac{\mu}{\epsilon+\omega-\mu} < 1$

$\Rightarrow \mu < \frac{\epsilon+\omega}{2}$

From this, it tells us that, the transmission rate μ relative to the recovery rateϵ and departure rate ω has a role in determining whether or not the disease prostitution on university campus by lecturers exist.

At disease-free

$$J(1,0,0) = \begin{bmatrix} -\omega & -\mu & 0 \\ 0 & \mu-\epsilon-\omega & 0 \\ 0 & \epsilon & -\omega \end{bmatrix}$$

Calculating for the eigenvalues;

$$J(1,0,0) = \begin{bmatrix} -\omega & -\mu & 0 \\ 0 & \mu-\epsilon-\omega & 0 \\ 0 & \epsilon & -\omega \end{bmatrix} = 0$$

We have;

$\lambda_1 = -\omega$

$\lambda_2 = -\epsilon$

$\lambda_3 = \mu - \omega - \epsilon$

From this we can say that the three eigenvalues are negatives ($2\mu > \omega + \epsilon$).Hence the disease-free equilibrium state is asymptotically unstable.

3.11 Endemic equilibrium state

$(s^*, p^*, r^*) = (a, b, c)$

where;

$a = \frac{\omega}{\omega+\mu p}$,

$b = \frac{\sqrt{\mu^2(\epsilon^2+\pi^2+\omega^2+2\omega\epsilon+2\omega\pi-2\epsilon\pi)+\pi^2(\omega^2-2\omega\mu)-2\omega\epsilon\mu\pi-2\omega^2\mu\pi}}{2\mu\pi}$,

$c = \frac{\epsilon p}{\omega+\pi p}$

From the male lecturer model matrix

$$J(s,p,r) = \begin{bmatrix} -\mu p-\omega & -\mu s & 0 \\ \mu p & \mu s+\pi r-\epsilon-\omega & \pi p \\ 0 & \epsilon-\pi r & -\pi p-\omega \end{bmatrix}$$

solving for the eigenvalues,$\lambda_{1},_{2}\ ,_{3}$

We obtained the characteristic equation;

$\lambda^3 - x\lambda^2 - y\lambda + z = 0$

Also, we obtained $\lambda_1 = -z$

$\Rightarrow \lambda^2 - x\lambda + d = 0$

from this;

Trace(T)=x and Determinant(D)=d

$\Rightarrow \lambda_{2,3} = \frac{T \pm \sqrt{T^2-4D}}{2}$

it also reveals that $\Rightarrow \lambda_1 < 0$ and $\lambda_{2,3} = \frac{T \pm \sqrt{T^2-4D}}{2}$

$T < 0, D > 0$

$\Rightarrow T^2 - 4D < 0$ Hence λ_2, λ_3 have negative real part. Therefore λ_1, λ_2 and λ_3 Having negative signs, the system is stable at the endemic. Thus the disease prostitution is asymptotically stable, depicting its existance among the male lecturers.

3.12 A Model on male lecturer and female student prostitution

This time also, we propose another model for male lectures and female students, Thus combining the two models. We have Non prostitute students (S_S) thus susceptible student group. Non prostitute lectures (S_L), they are the susceptible group. Prostitute students (P_S) group, Prostitute lectures (P_L), Recovered students (R_S) group. Recovered Lecturer (R_L) i.e. Minimum of 12months. The students and lectures join the campus in any two state as either susceptible ($A_S or A_L$) or as a prostitute ($P_S or P_L$). Once on campus a students or lecture may move from any of the state to any other prostitute state.

In the model,αN the number of students admitted into the system every academic year, ωN number of lecturers recruited by the university, α and ω the entering and departure rate from campus environment by female students and male lecturer respectively. ϕ is the rate at which a lecturer influences a female students to join prostitution,ψ is the rate at which a student influences a lecturer into prostitution,γ and ϵ are the recovery rates from prostitution by a student and a lecturer respectively , κ and π are the relapse rates from recovered to prostitution, σ and η entering rate of prostitute student and a lecturer respectively. In the equations, $S_S P_L$ and $S_L P_S$ shows the interaction between prostitute and non-prostitute whiles $P_L R_L$ and $P_S R_S$ is for prostitute and recovered. The conversion from prostitute to recover is assumed to be the result of a recovery process and is executed by the terms γP_S and ϵP_L.Recovered may only relapse to prostitution or leave the campus. Parameters ϕ, β, μ,and ψ,and κ and π' are the transmission rates and measure the effectiveness of the interactions between non-prostitute and prostitute, and recovered and prostitute respectively.

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the system of ODE's;

$\frac{dS_S}{dt} = \alpha N - \alpha S_S - \frac{\phi S_S P_L}{N} - \frac{\beta S_S P_S}{N}$

$\frac{dP_S}{dt} = \sigma P_S + \frac{\Psi S_L P_S}{N} + \frac{\beta S_S P_S}{N} + \frac{\kappa P_S R_S}{N} - \gamma P_S - (\alpha +$
$Psi\sigma)P_S$

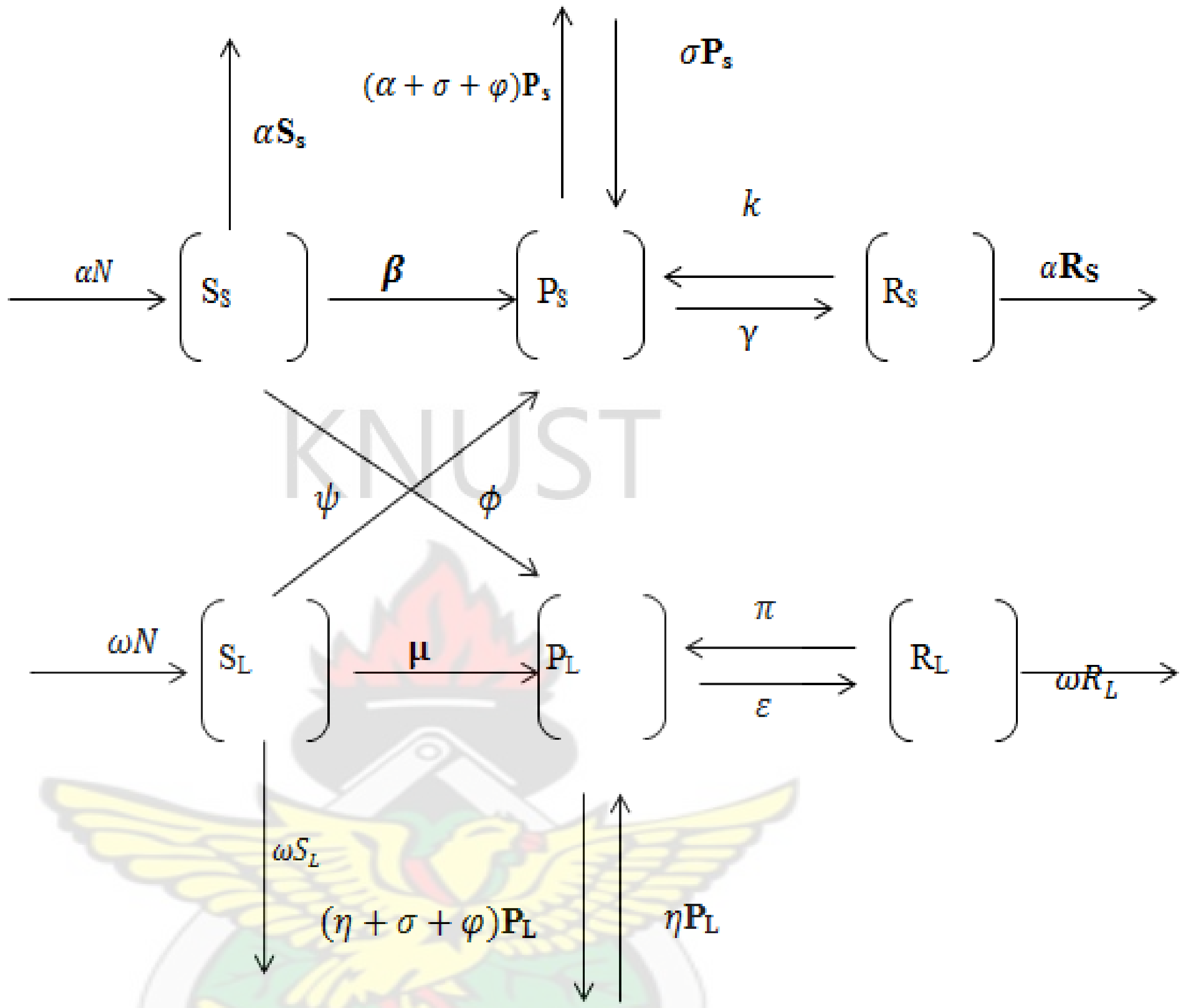
$\frac{dR_S}{dt} = \gamma P_S - \frac{\kappa P_S R_S}{N} - \alpha R_S$ 3.3.1

$\frac{dS_L}{dt} = \omega N - \frac{\Psi S_L P_S}{N} - \frac{\mu S_L P_L}{N} - \omega S_L$

$\frac{dP_L}{dt} = \eta P_L + \frac{\phi S_S P_L}{N} + \frac{\mu S_L P_L}{N} + \frac{\pi P_L R_L}{N} - \epsilon P_L - (\phi + \omega + \eta) P_L$

$\frac{dR_L}{dt} = \epsilon P_L - \frac{\pi P_L R_L}{N} - \omega R_L$

Figure 3.3: Compartmental diagram for female students and male lecturers



$N_S = S_S + P_S + R_S$ $N_L = S_L + P_L + R_L$

Rescaling

$s_s = \frac{S_S}{N}, p_s = \frac{P_S}{N}, r_s = \frac{R_S}{N}, s_l = \frac{S_L}{N}, p_l = \frac{P_L}{N}$ and $r_l = \frac{R_L}{N}$

We obtain

$\frac{ds_s}{dt} = \alpha - \beta s_s p_s - \phi s_s p_l - \alpha s_s$

$\frac{dp_s}{dt} = \sigma p_s + \beta s_s p_s + \kappa p_s r_s - \Psi s_l p_s - \gamma p_s - (\Psi + \alpha + \sigma) p_s$

$\frac{dr_s}{dt} = \gamma p_s - \kappa p_s r_s - \alpha r_s$

$\frac{ds_l}{dt} = \omega - \mu s_l p_l - \mu s_l - \Psi s_l p_s$

$\frac{dp_l}{dt} = \mu s_l p_l + \pi p_l r_l + \phi s_s p_l - \epsilon p_l - (\omega + \phi p_l)$

$\frac{dr_l}{dt} = \epsilon p_l - \pi p_l r_l - \omega r_l$

$s_s + p_s + r_s = 1, s_l + p_l + r_l = 1$

At equilibrium , we obtain;

$(s_s^*, p_s^*, r_s^*, s_l^*, p_l^*, r_l^*) = (1, 0, 0, 1, 0, 0)$ and

$(s_s^*, p_s^*, r_s^*, s_l^*, p_l^*, r_l^*) = (s_s, p_s, r_s, s_l, p_l, r_l)$

where

$s_s = \frac{\alpha}{\alpha+\phi p_l+\beta p_s}, r_s = \frac{\gamma p_s}{\kappa p_s+\alpha}, s_l = \frac{\omega}{\omega+\Psi p_s+\mu p_l}, r_l = \frac{\epsilon p_l}{\pi p_l+\omega}$

$$p_s = \frac{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}}{3(\sqrt[3]{2a})}$$
$$-\frac{\sqrt[3]{2}(3ac-b^2)}{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}} - \frac{b}{3a}$$

where

$a = \kappa\beta\psi + \kappa\beta\alpha\psi + \psi^2 - \beta\kappa\gamma\psi$

$b = \kappa\alpha^2\psi + \kappa\alpha\psi^2 + \beta\alpha\omega + \gamma\psi\beta\alpha + \alpha^2\psi\beta + \omega^2\alpha\beta - \beta\alpha\psi\kappa + \kappa\phi\alpha\psi + \kappa\phi + \psi^2 + \kappa\beta\alpha\mu$

$c = \kappa\alpha^2\omega + \alpha^3\gamma\psi + \alpha^3\Psi + \alpha^2\psi^2 + \alpha\gamma\beta\omega + \alpha^2\omega\beta - \alpha\beta\omega\kappa - \alpha^2\beta\psi + \kappa\alpha^2\mu + \kappa\alpha\mu\mu\psi +$
$\kappa\phi\gamma\psi + \alpha^2\phi\psi + \alpha\psi^2\phi + \alpha\gamma\mu\beta + \alpha^2\mu\beta + \psi\mu\alpha\beta - \alpha\beta\kappa\mu + \kappa\phi\alpha\mu + \kappa\phi\psi\mu$

$d = \alpha^2\gamma\mu + \alpha^3\mu + \alpha^2\psi\mu + \alpha\gamma\phi\omega + \alpha^2\phi\omega - \alpha^2\beta\mu + \alpha\phi\gamma\mu + \alpha^2\phi\mu + \alpha\phi\psi\mu + \alpha^2\gamma\omega +$
$\alpha^3\omega - \alpha^2\beta\omega$

$$p_l = \frac{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}}{3(\sqrt[3]{2a})}$$
$$-\frac{\sqrt[3]{2}(3ac-b^2)}{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}} - \frac{b}{3a}$$

where

$a = \phi^2\mu\pi + \omega\pi\mu\phi$

$b = \omega\phi^2\mu + \omega^2\pi\phi + \phi^2\omega\pi + \omega\pi\alpha\mu + \omega^2\phi\mu + \omega\epsilon\phi\mu + \omega\pi\beta + \phi\beta\mu\pi + \omega\pi\phi\psi + \phi^2\psi\pi -$
$\omega\phi\mu\pi - \psi\phi\pi\epsilon$

$c = \omega^2\phi + \omega^2\pi\alpha + \omega^3\phi + \omega^2\alpha\mu + \omega\epsilon\alpha\mu + \omega^2\epsilon\phi + \omega\epsilon\phi\psi + \phi\alpha\psi\pi + \omega\pi\beta\psi + \omega\phi\beta\pi + \omega\phi\beta\mu +$
$\omega\phi^2\psi + \omega^2\pi\beta + \alpha\phi\psi\pi + \omega\alpha\pi\psi + \omega^2\phi\psi + \omega^2\beta\mu + \omega\epsilon\beta\mu - \phi\alpha\pi - \omega\mu^2\beta - \omega^2\phi\mu - \omega\mu\alpha\pi$

$d = \omega\epsilon\beta\psi + \omega^2\beta\psi + \phi\beta\psi\omega + \omega\epsilon\psi + \omega^2\epsilon\beta + \omega^2\alpha\psi + \omega^3\beta + \omega^2\phi\beta + \omega^2\alpha\epsilon + \omega^3\alpha -$
$\omega^2\mu\beta - \omega^2\mu\alpha$

3.13 Disease-free equilibrium state

The Jacobian matrix for the equation is ;

$$J_DFE = \begin{bmatrix} -\alpha-\beta p_s-\phi p_l & -\beta s_s & 0 & 0 & -\phi s_s & 0 \\ \beta p_s & n & \kappa p_s & \psi p_s & 0 & 0 \\ 0 & \gamma-\kappa r_s & -\kappa p_s-\alpha & 0 & 0 & 0 \\ 0 & -\psi s_l & 0 & q & \mu s_l & 0 \\ \phi p_l & 0 & 0 & \mu p_l & m & \pi r_l \\ 0 & 0 & 0 & \epsilon-\pi r_l & -\pi r_l-\omega \end{bmatrix}$$

where

$n = \beta s_s + \psi s_l + \kappa r_s - \alpha - \psi - \gamma$

$m = \mu s_l + \phi s_s + \pi r_l - \omega - \phi - \epsilon$

$q = -\omega - \mu p_l - \psi p_s$

$$\text{At} J(s_s^*, p_s^*, r_s^*, s_l^*, p_l^*, r_l^*) = (1, 0, 0, 1, 0, 0)$$

We obtain

$$J(s_s^*, p_s^*, r_s^*, s_l^*, p_l^*, r_l^*) = \begin{bmatrix} -\alpha & -\beta & 0 & 0 & -\phi & 0 \\ 0 & \beta-\alpha-\gamma & 0 & 0 & 0 & 0 \\ 0 & \gamma & -\alpha & 0 & 0 & 0 \\ 0 & -\psi & 0 & -\omega & -\mu & 0 \\ 0 & 0 & 0 & 0 & \mu-\omega-\epsilon & 0 \\ 0 & 0 & 0 & 0 & \epsilon & -\omega \end{bmatrix}$$

There are two levels of infectives on the 'disease-free equilibrium R_0^s and R_0^l.

The first Reproductive number R_0^s is defined as the average number of secondary cases caused by a typical female prostitute in a non-prostitute campus environment. The basic reproductive number

R_0^s is calculated as; $R_0^s = \lambda^* \times (infectiousperiod) + 1$, where λ^* is the dominant eigenvalue.

$$R_0^s = (\beta - \alpha - \gamma)(\tfrac{1}{\gamma+\alpha}) + 1$$

$R_0^s = \frac{\beta}{\alpha+\gamma}$

The second Reproductive number R_0^l is defined as the average number of secondary cases caused by a typical male lecturer prostitute in a non-prostitute campus environment. The basic reproductive number R_0^l is given as;

$R_0^l = (\mu - \omega - \epsilon)(\frac{1}{\omega+\epsilon})$

$R_0^l = \frac{\mu}{\omega+\epsilon}$

3.14 special case when $\beta = \mu = 0$

When $\beta and \mu$ are zero, meaning infectious interaction,thus transmission rate is between student and lecturer. our R_0 are;

$R_0^s = \frac{\phi}{\alpha+\gamma}$

$R_0^l = \frac{\psi}{\epsilon+\omega}$

3.15 Local stability analysis

From the model

We obtain two infective,prostitute student and prostitute lecturer, leading to two basic reproductive numbers R_0^s and R_0^l. where

$R_0^s = \frac{\beta}{\alpha+\gamma}$ and $R_0^l = \frac{\mu}{\epsilon+\omega}$

For stable disease -free state,$R_0^s < 1$ and $R_0^l < 1$

$\Rightarrow \frac{\beta}{\alpha+\gamma} < 1$ and $\frac{\mu}{\epsilon+\omega} < 1$

Therefore the prostitution -free equilibrium (1, 0, 0, 1, 0, 0) is stable provided $\beta < \alpha + \gamma$ and $\mu < \epsilon + \omega$

For unstable disease -free state, then,

$R_0^s > 1$ and $R_0^l > 1$

$\Rightarrow \frac{\beta}{\alpha+\gamma} > 1$ and $\frac{\mu}{\epsilon+\omega} > 1$

This means $\beta > \alpha + \gamma$ and $\mu > \epsilon + \omega$

This means that the transmission rates β and μ relative to the recovery rates γ,ϵ, and the departure rate α, ω play a significant role in determining whether or not prostitution becomes established on campus.

From the ;

$R_0^s = \frac{\beta}{\alpha+\gamma}$ and $R_0^l = \frac{\mu}{\epsilon+\omega}$ It can be seen that increase in β, μ increases R_0^s and R_0^l respectively. And increase in α, ω, or γ, ϵ decreases R_0^s and R_0^l respectively.

At Disease-free;

$$J(1,0,0,1,0,0) = \begin{bmatrix} -\alpha & -\beta & 0 & 0 & -\phi & 0 \\ 0 & \beta-\alpha-\gamma & 0 & 0 & 0 & 0 \\ 0 & \gamma & -\alpha & 0 & 0 & 0 \\ 0 & -\psi & 0 & -\omega & -\mu & 0 \\ 0 & 0 & 0 & 0 & \mu-\omega-\epsilon & 0 \\ 0 & 0 & 0 & 0 & \epsilon & -\omega \end{bmatrix}$$

The eigenvalues at the disease-free equilibrium are;

$\lambda_1 = \lambda_2 = -\alpha$

$\lambda_3 = -\alpha - \gamma$

$\lambda_4 = \lambda_5 = -\omega$

$\lambda_6 = -\omega - \epsilon$

The negative eigenvalues means the disease-free state is unstable.

3.16 Endemic equilibrium state

From

$(s_s^*, p_s^*, r_s^*, s_l^*, p_l^*, r_l^*) = (s_s, p_s, r_s, s_l, p_l, r_l)$

Its jacobian matrix is ;

$J(s_s^*, p_s^*, r_s^*, s_l^*, p_l^*, r_l^*) =$

$$\begin{bmatrix} a & -\beta s_s & 0 & 0 & -\phi s_s & 0 \\ \beta p_s & b & \kappa p_s & \psi p_s & 0 & 0 \\ 0 & \gamma-\kappa r_s & -\kappa p_s-\alpha & 0 & 0 & 0 \\ 0 & -\psi s_l & 0 & c & \mu s_l & 0 \\ \phi p_l & 0 & 0 & \mu p_l & d & \pi r_l \\ 0 & 0 & 0 & 0 & \epsilon-\pi r_l & -\pi r_l-\omega \end{bmatrix}$$

where

$a=-\alpha-\beta p_s-\phi p_l$

$b=\beta s_s+\psi s_l+\kappa r_s-\alpha-\psi-\gamma$

$c=-\omega-\mu p_l-\psi p_s$

$d=\mu s_l+\phi s_s+\pi r_l-\omega-\phi-\epsilon$

$s_s=\frac{\alpha}{\alpha+\phi p_l+\beta p_s}, r_s=\frac{\gamma p_s}{\kappa p_s+\alpha}, s_l=\frac{\omega}{\omega+\Psi p_s+\mu p_l}, r_l=\frac{\epsilon p_l}{\pi p_l+\omega}$

$$p_s=\frac{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}}{3(\sqrt[3]{2a})}$$
$$-\frac{\sqrt[3]{2}(3ac-b^2)}{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}}-\frac{b}{3a}$$

where

$a=\kappa\beta\psi+\kappa\beta\alpha\psi+\psi^2-\beta\kappa\gamma\psi$

$b=\kappa\alpha^2\psi+\kappa\alpha\psi^2+\beta\alpha\omega+\gamma\psi\beta\alpha+\alpha^2\psi\beta+\omega^2\alpha\beta-\beta\alpha\psi\kappa+\kappa\phi\alpha\psi+\kappa\phi+\psi^2+\kappa\beta\alpha\mu$

$c=\kappa\alpha^2\omega+\alpha^3\gamma\psi+\alpha^3\Psi+\alpha^2\psi^2+\alpha\gamma\beta\omega+\alpha^2\omega\beta-\alpha\beta\omega\kappa-\alpha^2\beta\psi+\kappa\alpha^2\mu+\kappa\alpha\mu\mu\psi+$
$\kappa\phi\gamma\psi+\alpha^2\phi\psi+\alpha\psi^2\phi+\alpha\gamma\mu\beta+\alpha^2\mu\beta+\psi\mu\alpha\beta-\alpha\beta\kappa\mu+\kappa\phi\alpha\mu+\kappa\phi\psi\mu$

$d=\alpha^2\gamma\mu+\alpha^3\mu+\alpha^2\psi\mu+\alpha\gamma\phi\omega+\alpha^2\phi\omega-\alpha^2\beta\mu+\alpha\phi\gamma\mu+\alpha^2\phi\mu+\alpha\phi\psi\mu+\alpha^2\gamma\omega+$
$\alpha^3\omega-\alpha^2\beta\omega$

$$p_l=\frac{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}}{3(\sqrt[3]{2a})}$$
$$-\frac{\sqrt[3]{2}(3ac-b^2)}{\sqrt[3]{(\sqrt{(-27a^2d+9abc-2b^3)^2-4(3ac-b^2)^3}-27a^2d+9abc-2b^3)}}-\frac{b}{3a}$$

where

$a=\phi^2\mu\pi+\omega\pi\mu\phi$

$b=\omega\phi^2\mu+\omega^2\pi\phi+\phi^2\omega\pi+\omega\pi\alpha\mu+\omega^2\phi\mu+\omega\epsilon\phi\mu+\omega\pi\beta+\phi\beta\mu\pi+\omega\pi\phi\psi+\phi^2\psi\pi-$
$\omega\phi\mu\pi-\psi\phi\pi\epsilon$

$c = \omega^2\phi+\omega^2\pi\alpha+\omega^3\phi+\omega^2\alpha\mu+\omega\epsilon\alpha\mu+\omega^2\epsilon\phi+\omega\epsilon\phi\psi+\phi\alpha\psi\pi+\omega\pi\beta\psi+\omega\phi\beta\pi+\omega\phi\beta\mu+$
$\omega\phi^2\psi+\omega^2\pi\beta+\alpha\phi\psi\pi+\omega\alpha\pi\psi+\omega^2\phi\psi+\omega^2\beta\mu+\omega\epsilon\beta\mu-\phi\alpha\pi-\omega\mu^2\beta-\omega^2\phi\mu-\omega\mu\alpha\pi$
$d = \omega\epsilon\beta\psi + \omega^2\beta\psi + \phi\beta\psi\omega + \omega\epsilon\psi + \omega^2\epsilon\beta + \omega^2\alpha\psi + \omega^3\beta + \omega^2\phi\beta + \omega^2\alpha\epsilon + \omega^3\alpha -$
$\omega^2\mu\beta - \omega^2\mu\alpha$

From the matrix;

$$\begin{bmatrix} a & -\beta s_s & 0 & 0 & -\phi s_s & 0 \\ \beta p_s & b & \kappa p_s & \psi p_s & 0 & 0 \\ 0 & \gamma - \kappa r_s & -\kappa p_s - \alpha & 0 & 0 & 0 \\ 0 & -\psi s_l & 0 & c & \mu s_l & 0 \\ \phi p_l & 0 & 0 & \mu p_l & d & \pi r_l \\ 0 & 0 & 0 & 0 & \epsilon - \pi r_l & -\pi r_l - \omega \end{bmatrix}$$

The eigenvalues of the Jacobian matrix are the solutions of the characteristic equation
$|J - \lambda I| = 0$
That is

$$\begin{bmatrix} f & -\beta s_s & 0 & 0 & -\phi s_s & 0 \\ \beta p_s & g & \kappa p_s & \psi p_s & 0 & 0 \\ 0 & \gamma - \kappa r_s & h & 0 & 0 & 0 \\ 0 & -\psi s_l & 0 & q & \mu s_l & 0 \\ \phi p_l & 0 & 0 & \mu p_l & t & \pi r_l \\ 0 & 0 & 0 & 0 & \epsilon - \pi r_l & x \end{bmatrix} = 0$$

where
$f = -(\alpha + \beta p_s + \phi p_l + \lambda)$
$g = -(-\beta s_s - \psi s_l - \kappa r_s + \alpha + \psi + \gamma + \lambda)$
$h = -(\kappa p_s + \alpha + \lambda)$
$q = -(\omega + \mu p_l + \psi p_s + \lambda)$
$t = -(\mu s_l - \phi s_s - \pi r_l + \omega + \phi + \epsilon + \lambda)$

$x = -(\pi r_l + \omega + \lambda)$

The eigenvalues can be obtained as fellow;

$(\alpha + \beta p_s + \phi p_l + \lambda)(-\beta s_s - \psi s_l - \kappa r_s + \alpha + \psi + \gamma + \lambda)(\kappa p_s + \alpha + \lambda)(\omega + \mu p_l + \psi p_s + \lambda)(\mu s_l - \phi s_s - \pi r_l + \omega + \phi + \epsilon + \lambda)(\pi r_l + \omega + \lambda) - (\pi \epsilon r_l - \pi^2 r_l^2 - \epsilon\omega + \pi\omega r_l)(\phi\mu\psi\beta s_s s_l p_s p_l)^2(\gamma\pi\kappa r_l p_s - \pi\kappa^2 p_s r_s r_l)$

To simplify let

$A_1 = \alpha + \beta p_s + \phi p_l, A_2 = -\beta s_s - \psi s_l - \kappa r_s + \alpha + \psi + \gamma$

$A_3 = \kappa p_s + \alpha, A_4 = \omega + \mu p_l + \psi p_s$

$A_5 = \mu s_l - \phi s_s - \pi r_l + \omega + \phi + \epsilon, A_6 = \pi r_l + \omega$

and $K = (\pi\epsilon r_l - \pi^2 r_l^2 - \epsilon\omega + \pi\omega r_l)(\phi\mu\psi\beta s_s s_l p_s p_l)^2(\gamma\pi\kappa r_l p_s - \pi\kappa^2 p_s r_s r_l) = 0$

This implies

$(\lambda + A_1)(\lambda + A_2)(\lambda + A_3)(\lambda + A_4)(\lambda + A_5)(\lambda + A_6) - K = 0$

$$\lambda^6 + B_1\lambda^5 + B_2\lambda^4 + B_3\lambda^3 + B_4\lambda^2 + B_5\lambda + B_6 = 0 \qquad 3.3$$

Where

$B_1 = A_6 + A_5 + A_4 + A_3 + A_2 + A_1$

$B_2 = A_4(A_3 + A_2 + A_1) + A_3(A_2 + A_1) + A_2A_1 + A_5A_6$

$B_3 = A_5(A_4 + A_3 + A_2 + A_1) + A_4(A_3 + A_2 + A_1) + A_3(A_2 + A_1) + A_4A_5A_6 + A_2A_1$

$B_4 = A_6(A_5 + A_4 + A_3 + A_2 + A_1) + A_5(A_4 + A_3 + A_2 + A_1) + A_4(A_3 + A_2 + A_1) + A_3(A_2 + A_1) + A_2A_1$

$B_5 = A_6A_5A_4A_3A_2 + A_6A_5A_4A_3A_1 + A_6A_5A_4A_2A_1 + A_6A_5A_3A_2A_1 + A_5A_4A_3A_2A_1$

$B_6 = A_6A_5A_4A_3A_2A_1 - K$

Using the Routh-Hurwitz Criteria a method for determining whether a linear system is stable or not by examining the locations of the roots of the characteristic equation of the system. The method determines criteria that give necessary and sufficient conditions for all of the roots of the characteristic polynomial (with real coefficients) to lie in the left half of the complex plane are known as Routh-Hurwitz criteria (Flores, 2011).it does not actually compute the roots but consider the characteristic equation.

By Routh-Hurwitz criteria To determine whether this system is stable or not, check the following conditions: 1). Two necessary but not sufficient conditions that all the roots have negative real parts are; a) All the polynomial coefficients must have the same sign. b) All the polynomial coefficients must be nonzero. 2. If condition (1) is satisfied, then compute the Routh-Hurwitz array to obtain a matrix as follows: For the polynomial;

$P(\lambda) = \lambda^n + B_1\lambda^{n-1} + ... + B_{n-1}\lambda + B_n$

Where the coefficients B_i are real constants,$i = 1, ..., n$, define the n Hurwitz matrices using the coefficients B_i of the characteristic polynomial;

$$H_1 = (B_1),\ H_2 = \begin{pmatrix} B_1 & 1 \\ B_3 & B_2 \end{pmatrix}, H_3 = \begin{pmatrix} B_1 & 1 & 0 \\ B_3 & B_2 & B_1 \\ B_5 & B_4 & B_3 \end{pmatrix}$$

$$\text{And } H_n = \begin{pmatrix} B_1 & 1 & 0 & 0 & ... & 0 \\ B_3 & B_2 & B_1 & 1 & ... & 0 \\ B_5 & B_4 & B_3 & B_2 & ... & 0 \\ . & . & . & . & ... & . \\ . & . & . & . & ... & . \\ . & . & . & . & ... & . \\ 0 & 0 & 0 & 0 & ... & B_n \end{pmatrix}$$

Where $B_j = 0, If j > n$. The necessary condition that all roots are negative or have negative real parts is that the determinant of the Routh-Hurwitz matrices are positive;$det(H_j) > 0, j = 1, 2, ..., n$. The number of changes of sign equals the number of roots with positive real parts.

Considering the characteristic equation 3.3, where n=6, The Routh-Hurwitz Criteria are $B_1 > 0, B_2 > 0, B_3 > 0, B_4 > 0, B_5 > 0, B_6 > 0$

For

$$H_1 = B_1, H_2 = \begin{pmatrix} B_1 & 1 \\ B_3 & B_2 \end{pmatrix}, H_3 = \begin{pmatrix} B_1 & 1 & 0 \\ B_3 & B_2 & B_1 \\ B_5 & B_4 & B_3 \end{pmatrix}, H_4 = \begin{pmatrix} B_1 & 1 & 0 & 0 \\ B_3 & B_2 & B_1 & 1 \\ B_5 & B_4 & B_3 & B_2 \\ 0 & B_6 & B_5 & B_4 \end{pmatrix}$$

$$H_5 = \begin{pmatrix} B_1 & 1 & 0 & 0 & 0 \\ B_3 & B_2 & B_1 & 1 & 0 \\ B_5 & B_4 & B_3 & B_2 & 1 \\ 0 & B_6 & B_5 & B_4 & B_3 \\ 0 & 0 & 0 & B_6 & B_5 \end{pmatrix}, H_6 = \begin{pmatrix} B_1 & 1 & 0 & 0 & 0 & 0 \\ B_3 & B_2 & B_1 & 1 & 0 & 0 \\ B_5 & B_4 & B_3 & B_2 & 1 & 0 \\ 0 & B_6 & B_5 & B_4 & B_3 & B_2 \\ 0 & 0 & 0 & B_6 & B_5 & B_4 \\ 0 & 0 & 0 & 0 & 0 & B_6 \end{pmatrix}$$

And

$det(H_1) = B_1 > 0,$

$$det(H_2) = \begin{pmatrix} B_1 & 1 \\ 0 & B_2 \end{pmatrix} = B_1B_2 > 0,$$

$$det(H_3) = \begin{pmatrix} B_1 & 1 & 0 \\ B_3 & B_2 & B_1 \\ 0 & 0 & B_3 \end{pmatrix} = B_1B_2 - B_3 > 0,$$

$$det(H_4) = \begin{pmatrix} B_1 & 1 & 0 & 0 \\ B_3 & B_2 & B_1 & 1 \\ 0 & B_4 & B_3 & B_2 \\ 0 & 0 & 0 & B_4 \end{pmatrix} = B_1B_2B_3 - B_3^2 - B_1^2B_4 > 0$$

$$det(H_5) = \begin{pmatrix} B_1 & 1 & 0 & 0 & 0 \\ B_3 & B_2 & B_1 & 1 & 0 \\ 0 & B_4 & B_3 & B_2 & B_1 \\ 0 & 0 & 0 & B_4 & B_3 \\ 0 & 0 & 0 & 0 & B_5 \end{pmatrix} = B_1B_2B_3 - B_3^2 - B_1^2B_4, (B_1B_4 - B_5)(B_1B_2B_3 -$$

$B_3^2 - B_1^2 B_4) - B_5(B_1 B_2 - B - 3)^2 - B_1 B_5^2 > 0$

And

$$det(H_6) = \begin{pmatrix} B_1 & 1 & 0 & 0 & 0 & 0 \\ B_3 & B_2 & B_1 & 1 & 0 & 0 \\ 0 & 0 & B_3 & B_2 & B_1 & 0 \\ 0 & 0 & 0 & B_4 & B_3 & B_2 \\ 0 & 0 & 0 & 0 & B_5 & B_4 \\ 0 & 0 & 0 & 0 & 0 & B_6 \end{pmatrix} = B_i > 0, i = 1, 2, 3, 4, 5, 6$$

Now we can see that all determinants of the Hurwitz matrices are positive,thus $det(H_1) > 0, det(H_2) > 0, det(H_3) > 0, det(H_4) > 0, det(H_5) > 0$ and $det(H_6) > 0$ which means all the eigenvalues of the endemic jacobian matrix have negative real part. Therefore, Endemic equilibrium state is stable.

3.17 Sensitivity Analysis

By sensitivity analysis, we are able to predict the outcome of a decision in different situations. Sensitivity analysis is a way to predict the outcome of a decision if a situation turns out to be different compared to the key prediction(s).

Sensitivity analysis addresses the issue of an evaluation of how much each input is contributing to the output uncertainty, performing the role of ordering by importance the strength and relevance of the inputs in determining the variation in the output.

Chapter 4

Sensitivity Analysis

In this chapter, we are going to use the solutions to the equations, R_0 and the matrix obtain in the analysis of our model both in the Disease - free and Endemic state in all the three models in chapter three to do the numerical analysis.And also to study the effect of the parameters on the model.

For numerical illustration values are assigned to the parameters for analysis.

4.1 Student model

we do the numerical analyses on the student model using the following parameter values;

$\alpha = 0.38, \beta = 0.67, \gamma = 0.54, \sigma = 0.123, \kappa = 0.45.$

4.2 Disease -free equilibrium (R_0)

We calculate for R_0

We have

$R_0 = \frac{\beta}{\alpha+\gamma-\beta}$

$\Rightarrow R_0 = \frac{0.67}{0.38+0.54-0.67}$

$\Rightarrow R_0 = 2.68$

$\Rightarrow R_0 \simeq 3$

For $R_0 \simeq 3 > 1$ means the disease -free equilibrium is asymptotically unstable.Thus the disease prostitution does not die out

A local sensitivity analysis is performed by varying the model input parameters to determine which parameter has the greatest impact on the reproductive number.

Varying the parameters into the model to determine their impact on the Reproductive number, we have fig 4.1

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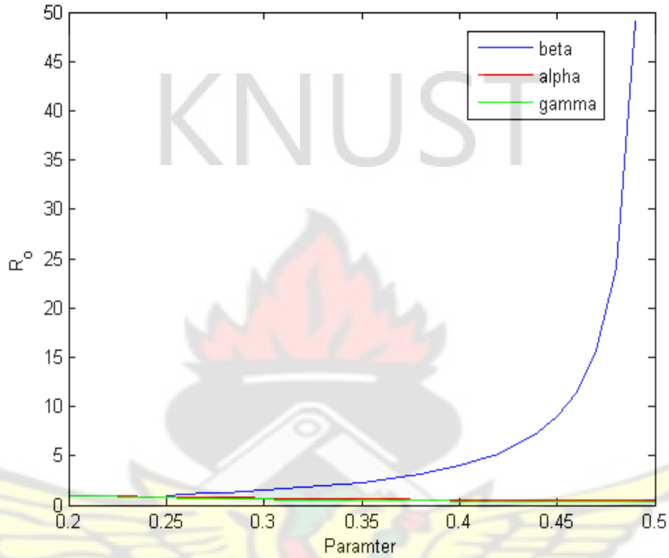
Figure 4.1: Graph of R_0 for students against changes in Parameters



It reveals that R_0 is more sensitive to infectious rate β than the recovery rate γ, and departure rate α . As the rate β is increase, the R_0 also increases, showing the spread of student prostitution on campus increase. Again, when recovery rate γ,or departure rate α increase the R_0 decrease, but in this case the decrease is not that much as compared to the change in β against the R_0.

4.3 Analysis of SIR and Parameters

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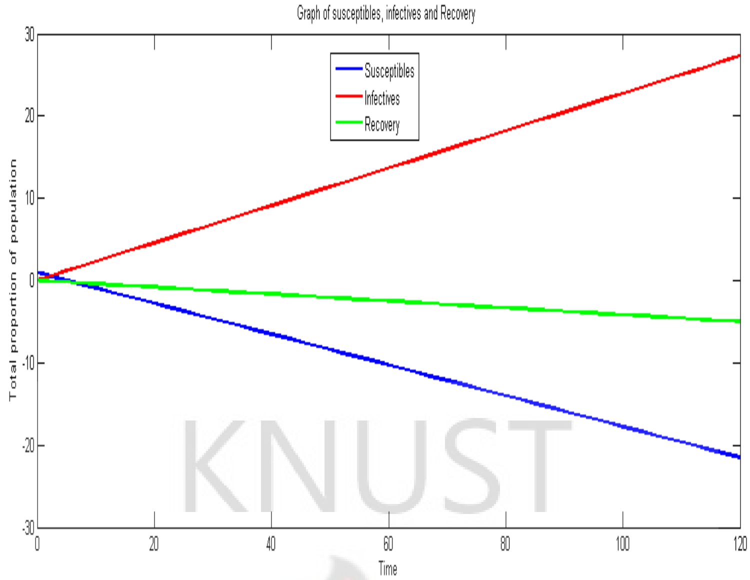
From figure 4.2, we observe that the infectious is increasing whiles the susceptible and the recovery are decreasing with time.But the decrease in the recovery is not as much as that of the susceptible indicating as more student are moving to

Figure 4.2: Graph of Susceptible, Infectious,Recovery against time



the infectious,the rate of recovery is low hence the existence and increase of the disease among student with time.

Varying the value of β

Figure 4.3: Graph of $\beta = 0.44$ against time

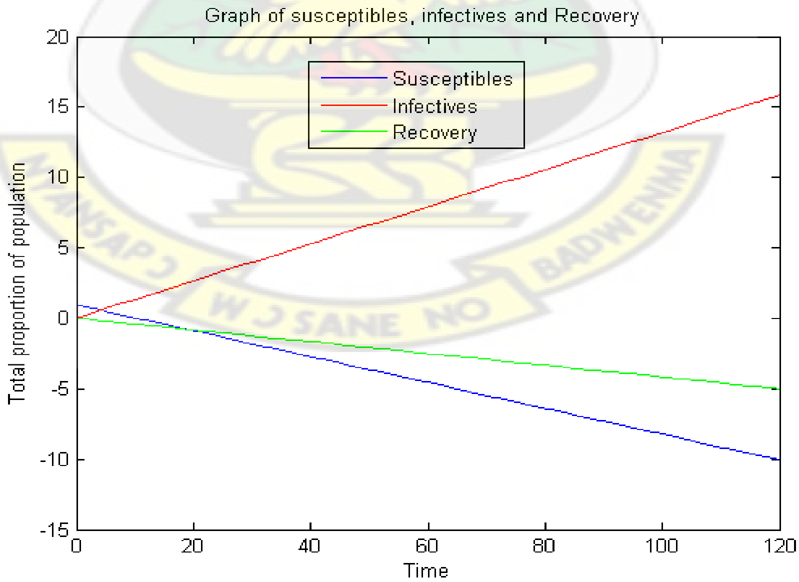
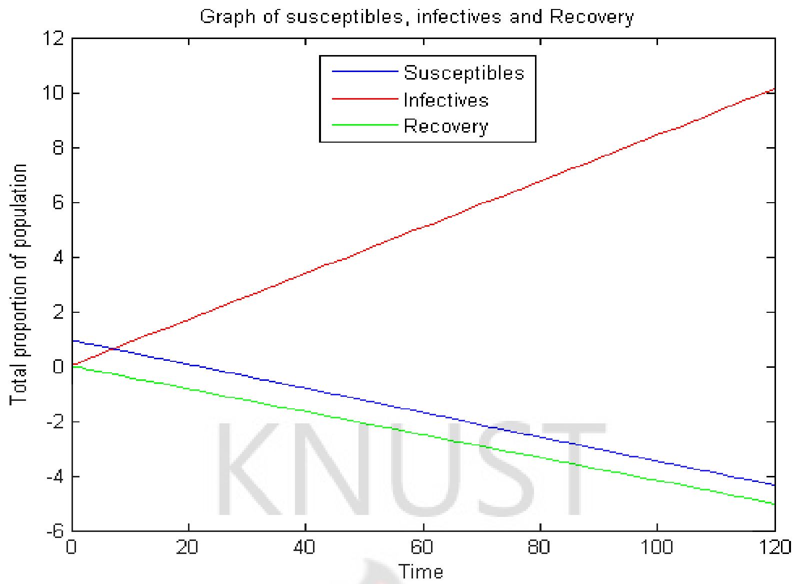


Figure 4.4: Graph of $\beta = 0.22$ against time



From figure 4.3 and 4.4, As β decrease the recovery also decreases more compared to the susceptible; indicating that recovery occurs when there is a disease.

4.4 Endemic state

From

$$J_s = \begin{bmatrix} -\beta p - \alpha & -\beta s & 0 \\ \beta p & \beta s + \kappa r - \gamma - \alpha & \kappa p \\ 0 & \gamma - \kappa r & -\kappa p - \alpha \end{bmatrix}$$

$$\text{We obtained } J_s = \begin{bmatrix} -0.6744 & -0.3775 & 0 \\ 0.2944 & -0.0881 & 0.2329 \\ 0 & 0.0856 & -0.6129 \end{bmatrix}$$

The eigenvalues are;

λ_1, λ_2 and λ_3 are -0.3800, -0.4083 and -0.5872 respectively. With these eigenvalues the system is asymptotically stable in student prostitution model.The disease prostitution persist among student in the university campus.

4.5 Male lecturers model

4.6 Disease -free equilibrium (R_0)

For $\eta = 0.23, \epsilon = 0.54, \pi = 0.45, \mu = 0.67, \omega = 0.38$,

$R_0 = \frac{\mu}{\epsilon+\omega-\mu}$

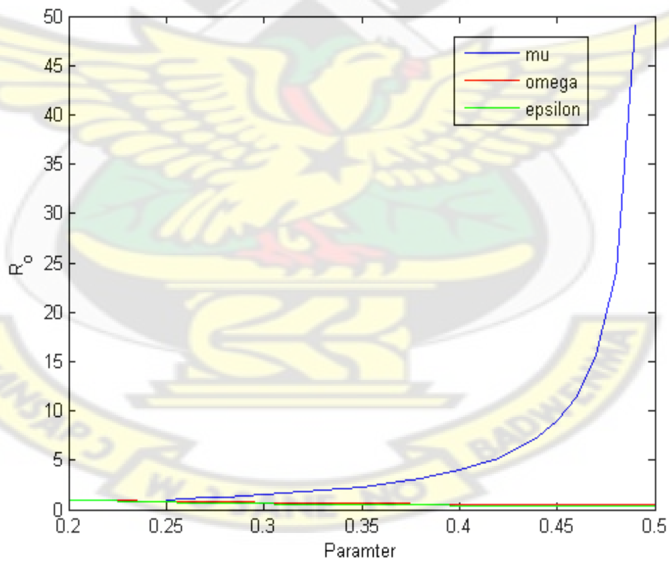
$\Rightarrow R_0 = \frac{0.67}{0.38+0.54-0.67}$

$\Rightarrow R_0 = 2.68$

$\Rightarrow R_0 \simeq 3$

For $R_0 \simeq 3 > 1$ means the disease -free equilibrium is asymptotically unstable. Varying the parameters into the model to determine their impact on the Reproductive number, we have fig 4.5

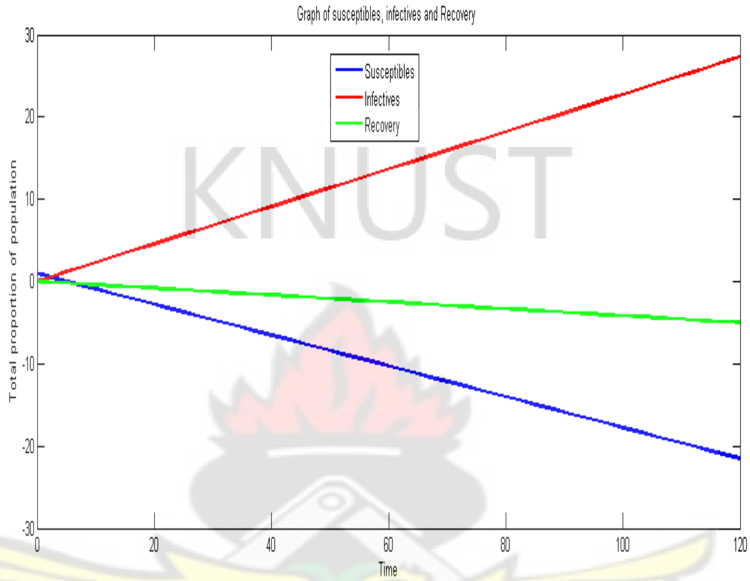
Figure 4.5: Graph of R_0 for lecturers against changes in Parameters



It reveals that R_0 is more sensitive to infectious rates μthan the recovery rate ϵ, and departure rate ω. As the rate μ is increase, the R_0 in also increases, showing the spread of lecturer prostitution on campus increase. Again, when recovery rate ϵ,or departure rate ω increase the R_0 decrease, but in this case the decrease is not that much as compared to the change in μ against the R_0.

4.7 analysis of SIR and parameters

Figure 4.6: Graph of Susceptible, Infectious,Recovery against time



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From figure 4.6, we also observe that the infectious is increasing whiles the susceptible and the recovery are decreasing with time.But the decrease in the recovery is not as much as that of the susceptible indicating as more student are moving to the infectious,the rate of recovery is low hence the existence and increase of the disease among male lecturers with time.

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From figure 4.7 and 4.8, As β decrease the recovery also decreases more compared to the susceptible; indicating that recovery occurs when there is a disease.

Figure 4.7: Graph of $\mu = 0.44$ against time

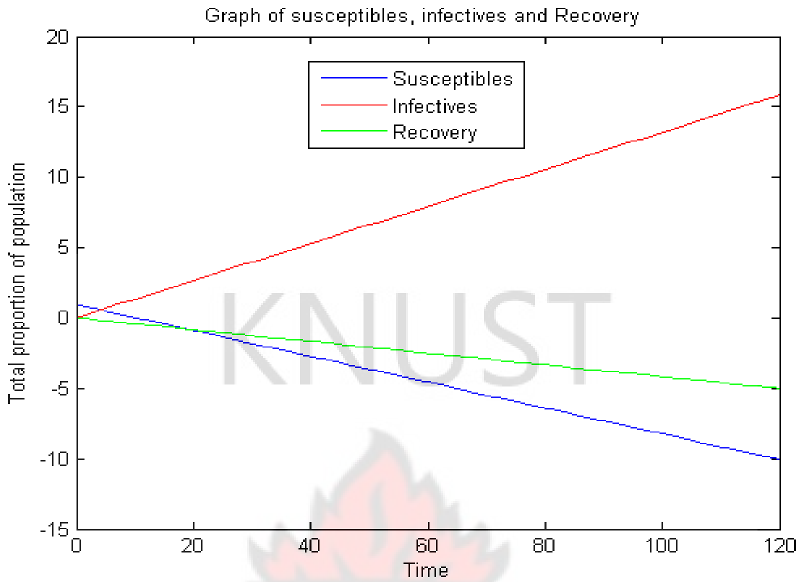
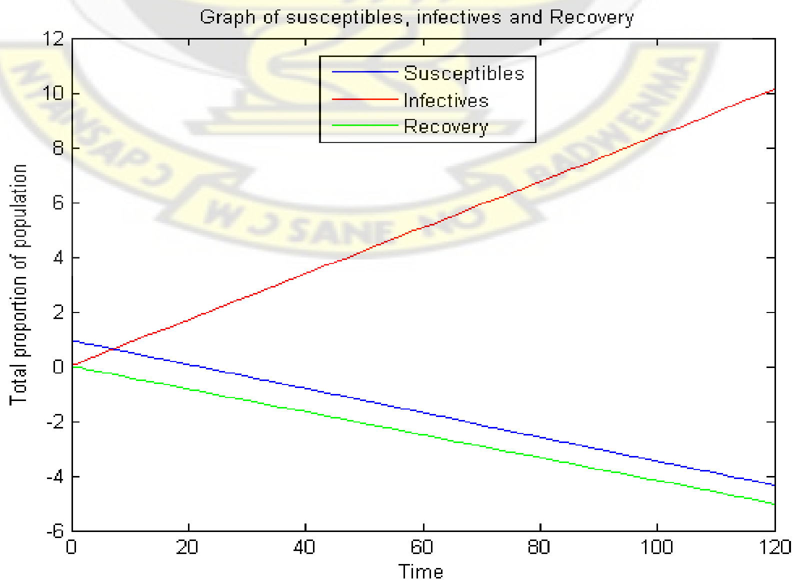


Figure 4.8: Graph of $\mu = 0.22$ against time



4.8 Endemic state

From

$$J_l = \begin{bmatrix} -\mu p - \omega & -\mu s & 0 \\ \mu p & \mu s + \pi r - \epsilon - \omega & \pi p \\ 0 & \epsilon - \pi r & -\pi p - \omega \end{bmatrix}$$

$$\text{We obtained } J_l = \begin{bmatrix} -0.6744 & -0.3775 & 0 \\ 0.2944 & -0.0881 & 0.2329 \\ 0 & 0.0856 & -0.6129 \end{bmatrix}$$

The eigenvalues are;

λ_1, λ_2 and λ_3 are -0.3800, -0.4083 and -0.5872 respectively. With these eigenvalues the system is asymptotically stable in lecturer prostitution models. The prostitution persist among male lecturers on the university campus.

4.9 The combined model for female students and male lecturers

For $\alpha = 0.06, \omega = 0.02, \beta = 0.48, \mu = 0.48, \gamma = 0.11, \epsilon = 0.13, \kappa = 0.20, \pi = 0.20, \psi = 0.33, \phi = 0.32, \eta = 0.07, \sigma = 0.10$

We calculated

$R_0^s = 2.8235$ and $R_0^l = 3.20$

The sensitivity analysis indicate that the R_0 for R_0^s and R_0^l is more sensitive to the infectious rates β, μ than the recovery rates γ, ϵ and departure rates α, ω respectively. It can be observe that when β is double R_0^s is double so as when μ is double R_0^l. meaning doubling the infectious rates the growth of the disease increases. Again, doubling $\alpha or \gamma$, R_0^s does not double but decreases but the decrease is not double. And doubling $\epsilon or \omega$, R_0^l does not double but decreases but does not double the decrement. It then means that , the transmission rate β, μ relative to the recovery rate γ, ϵ and departure rate α, ω play a significant role in determining the act of prostitution being established and the rate at which it grows on campus. The graphs below show the changes in parameter values correspond to the changes in R_0

Figure 4.9: Graph of R_0^s against changes in Parameters

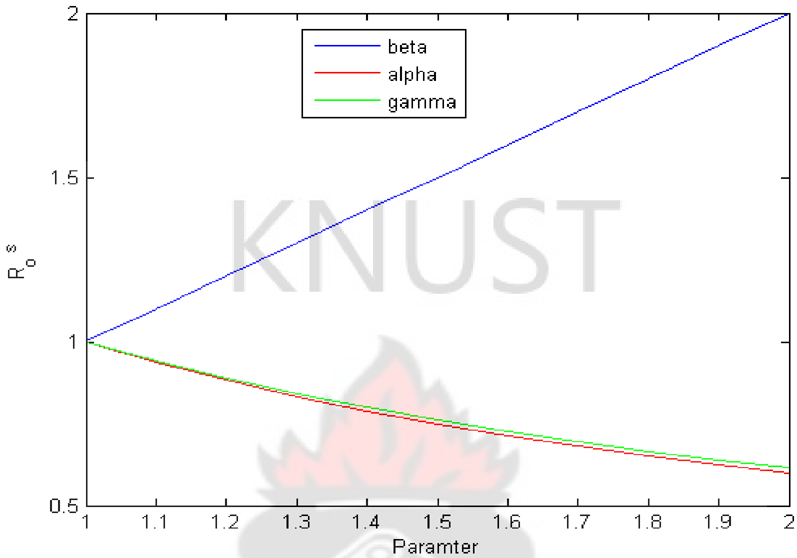
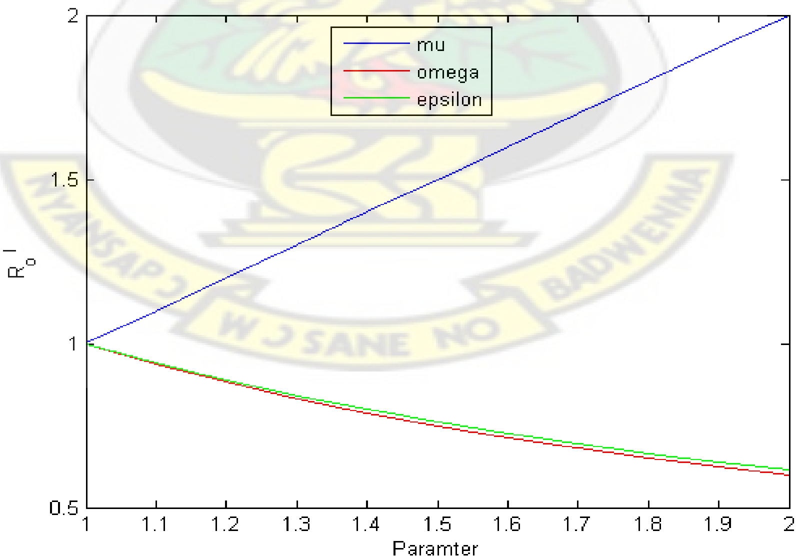


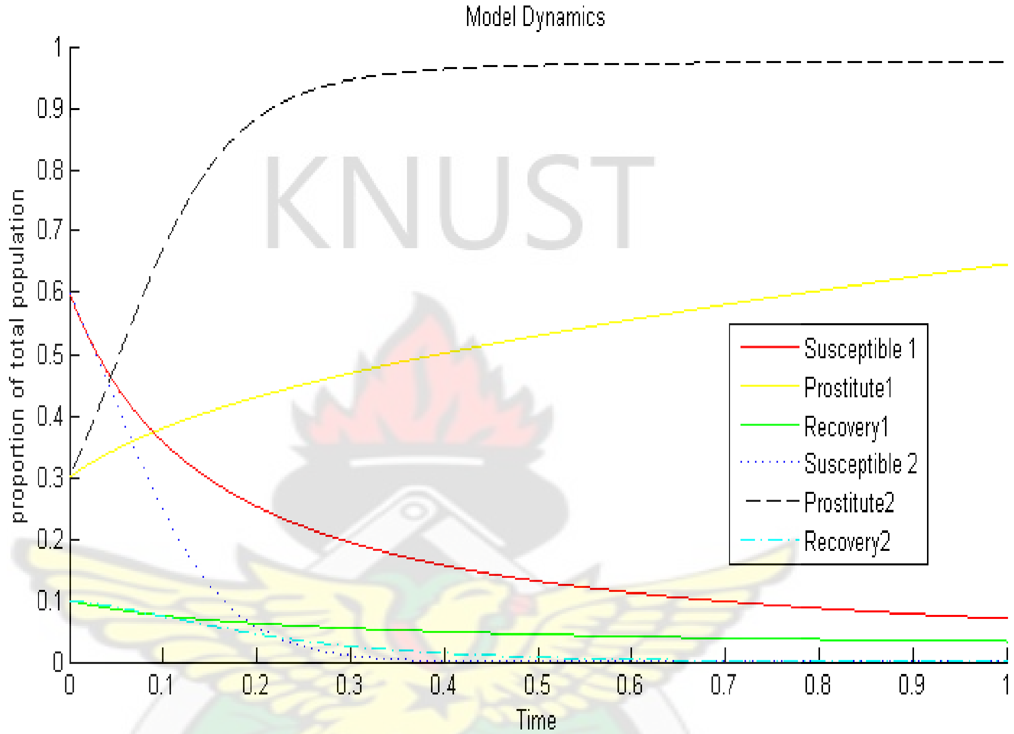
Figure 4.10: Graph of R_0^l against changes in Parameters



4.10 Sensitivity analysis of SIR

The graph of the model equations;

Figure 4.11: Model dynamics



Taking the compartment separately, we have;

Figure 4.12: Model dynamics on female students

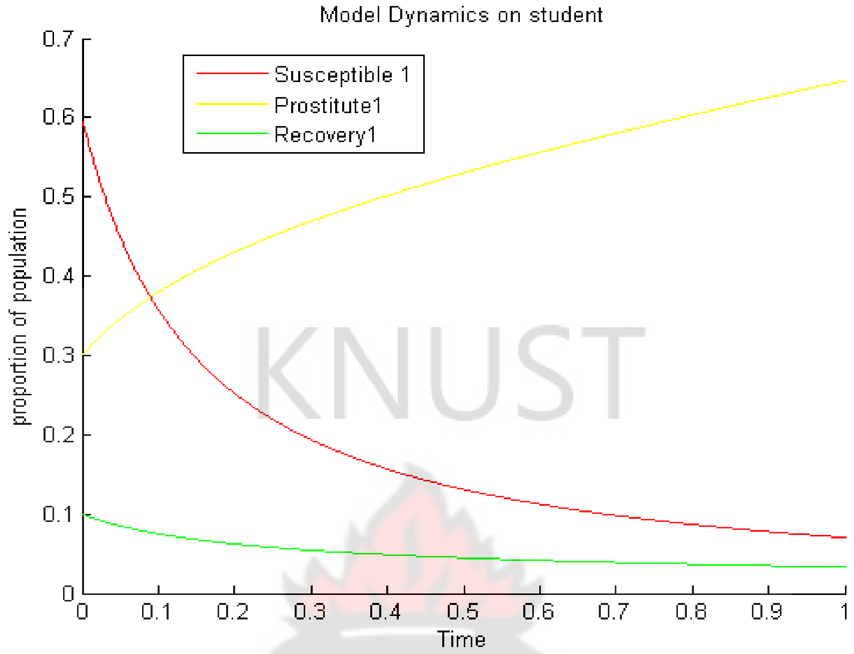
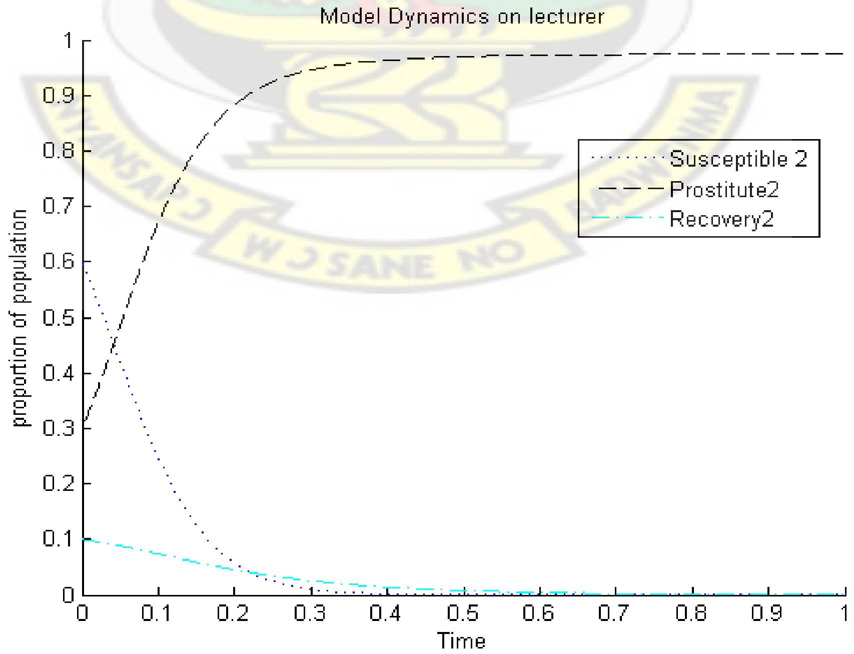


Figure 4.13: Model dynamics on male lecturers



It can be observe that infectious is increasing whiles the susceptibles and recoveries are decreasing.We can see that the infectious for the male lecturers inrcreases sharply and reduces the rate of increments.This confirms the work of Reymond(2004) that male the demand group which is the primary factor when measures are put in place,it will reduce the spread of the disease.

4.11 Endemic state

From the jacobian matrix is ;

$$J = \begin{bmatrix} -\alpha - \beta p_s - \phi p_l & -\beta s_s & 0 & 0 & -\phi s_s & 0 \\ \beta p_s & \beta s_s + \psi s_l + \kappa r_s - \alpha - \psi - \gamma & \kappa p_s & \psi p_s & 0 & 0 \\ 0 & \gamma - \kappa r_s & -\kappa p_s - \alpha & 0 & 0 & 0 \\ 0 & -\psi s_l & 0 & -\omega - \mu p_l - \psi p_s & \mu s_l & 0 \\ \phi p_l & 0 & 0 & \mu p_l & \mu s_l + \phi s_s + \pi r_l - \omega - \phi - \epsilon & \pi r_l \\ 0 & 0 & 0 & 0 & \epsilon - \pi r_l & -\pi r_l - \omega \end{bmatrix}$$

Substituting the parameter values into the jacobian matrix at the endemic state

We obtain ;

$$J_E = \begin{bmatrix} -0.4646 & -0.1549 & 0 & 0 & -0.1065 & 0 \\ 0.0746 & -0.2182 & 0.0311 & 0.0498 & 0 & 0 \\ 0 & 0.0724 & -0.0911 & 0 & 0 & 0 \\ 0 & -0.0794 & 0 & -0.1613 & -0.1141 & 0 \\ 0.0513 & 0 & 0 & 0.0715 & -0.1826 & 0.0569 \\ 0 & 0 & 0 & 0 & 0.0731 & -0.0969 \end{bmatrix}$$

Solving for the eigenvalues and use it in the analysis.

$$J(I-\lambda) = \begin{bmatrix} -(0.4646+\lambda) & -0.1549 & 0 & 0 & -0.1065 & 0 \\ 0.0746 & -(0.2182+\lambda) & 0.0311 & 0.0498 & 0 & 0 \\ 0 & 0.0724 & -(0.0911+\lambda) & 0 & 0 & 0 \\ 0 & -0.0794 & 0 & -(0.1613+\lambda) & -0.1141 & 0 \\ 0.0513 & 0 & 0 & 0.0715 & -(0.1826+\lambda & 0.0569 \\ 0 & 0 & 0 & 0 & 0.0731 & -(0.0969+\lambda) \end{bmatrix}$$

We obtain the eigenvalues to be ;

$$\lambda_1 = -0.3831$$

$$\lambda_2 = -0.2147 + 0.0934i$$

$$\lambda_3 = -0.2147 - 0.0934i$$

$$\lambda_4 = -0.2482$$

$$\lambda_5 = -0.0837$$

$$\lambda_6 = -0.0702$$

With these negative real eigenvalues the system is asymptotically stable in female students and male lecturers model.Therefore,the culture of prostitution will persist on the university campus.

Chapter 5

Conclusion

In this work promiscuous life style on campus has been analyzed mathematically. We introduced an SIR mathematical model capturing the dynamics of campus prostitution, describing the existence and spread of the disease prostitution. The stability analysis of the disease-free on the basic reproductive numbers reveals asymptotically unstable equilibrium state and the eigenvalues of the endemic jacobian matrix reveals stable endemic state. Graphical result is presented and discussion on them is done. The numerical analysis confirms unstable disease free equilibrium point and stable endemic equilibrium point, implying prostitution cannot die out on university campus but can be minimize the spread and infection. Also it reveals that transmission rate is more sensitive to the model than the recovery and departure rate, even at the special case when $R_0^s = \frac{\phi}{\alpha+\gamma}$ and $R_0^l = \frac{\psi}{\epsilon+\omega}$

This suggests that one possible technique in reducing campus prostitution problems is to modify the recruitment patterns. Specifically, our research suggests that campus prostitution may be reduced by minimizing the ability of admitting of prostitute student and and recruitment of prostitute lecturer to directly admitting and recruiting non-prostitue. This may be accomplished by designing effective control strategies and systems to limit the factor demand and supply among student and lecturers. .

5.1 Recommendation

We recommend further studies on;

- SIR model using non constant population.

- SIR model where recovery move to the susceptible
- Different method of analysis
- Use a primary data for parameter values into the model.

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Appendix A

CODES FOR FIGURE 4.1

Title:Graph of R_0 against changes in parameter

clear, clc;

$beta = 0.25 : 0.01 : 0.5$ $alpha = [0.2]$; $gamma = [0.3]$;

$R_0 = beta./(alpha + gamma - beta)$

$plot(beta, R_0,'b')$

hold on

$alpha = 0.2 : 0.01 : 0.5$ $beta = [0.25]$; $gamma = [0.3]$; $R_0 = beta./(alpha + gamma - beta)$ $plot(alpha, R_0,'r')$

hold on

$gamma = 0.2 : 0.01 : 0.5$ $beta = [0.15]$; $a = [0.1]$;

$R_0 = beta./(alpha + gamma - beta)$ $plot(gamma, R_0,'g')$

$xlabel('Paramter')$

$ylabel('R_o')$

$legend('beta','alpha','gamma')$

CODES FOR FIGURE 4.2

Title:Graph of susceptible,Infectious,Recovery against time

clear, clc;

$functionypsir = ypsir(t, y)$ $alpha = 0.01; beta = 0.88; gamma = 0.03; kapa = 0.62; s = 0.653; p = 0.332; r = 0.2090; N = 1;$

$ypsir(1) = alpha - beta * s * p - alpha * s;$

$ypsir(2) = beta * s * p + kapa * p * r - gamma * p - alpha * p;$

$ypsir(3) = gamma*p-kapa*p*r-alpha*r; ypsir = [ypsir(1)ypsir(2)ypsir(3)]';$

$to = 0; tf = 120;$ $yo = [0.960.030.01]$

$[t, y] = ode45('ypsir', [totf], yo);$

$plot(t, y(:, 1), 'b', t, y(:, 2), 'r', t, y(:, 3), 'g')$

$legend('Susceptibles', 'Infectives', 'Recovery'),$

$ylabel('Totalproportionofpopulation'),$

$xlabel('Time'),$

title('Graph of susceptibles, infectives and Recovery ')

CODES FOR FIGURE 4.3 and 4.4

Title:Graphs of beta =0.44,and beta =0.22 against time respectivel

clear, clc;

function - $ypsir = ypsir(t, y)$ $alpha = 0.02; beta = 0.44; andbeta = 0.22; gamma = 0.03; kapa = 0.62; s = 0.653; p = 0.332; r = 0.2090; N = 1;$

$ypsir(1) = alpha - beta * s * p - alpha * s;$

$ypsir(2) = beta * s * p + kapa * p * r - gamma * p - alpha * p;$

$ypsir(3) = gamma*p - kapa*p*r - alpha*r; ypsir = [ypsir(1)ypsir(2)ypsir(3)]';$

$to = 0; tf = 120;$ $yo = [0.960.030.01]$

$[t, y] = ode45('ypsir', [totf], yo);$

$plot(t, y(:, 1), 'b', t, y(:, 2), 'r', t, y(:, 3), 'g')$

$legend('Susceptibles', 'Infectives', 'Recovery'),$

$ylabel('Totalproportionofpopulation'),$

$xlabel('Time'),$

title('Graph of susceptibles, infectives and Recovery ')

Appendix B

CODES FOR FIGURE 4.5

Title:Graph of R_0 against changes in parameter

clear, clc;

$mu = 0.25 : 0.01 : 0.5\ omega = [0.2]; epsilon = [0.3];$

$R_0 = mu./(omega + epsilon - mu)$

$plot(mu, R_0,' b')$

hold on

$omega = 0.2 : 0.01 : 0.5\ mu = [0.25]; epsilon = [0.3]; R_0 = mu./(omega + e[silon] - mu)\ plot(omega, R_0,' r')$

hold on

$epsilon = 0.2 : 0.01 : 0.5\ mu = [0.15]; omega = [0.1];$

$R_0 = beta./(omega + epsilon - mu)\ plot(epsilon, R_0,' g')$

$xlabel('Paramter')$

$ylabel('R_o')$

$legend('mu',' omega',' epsilon')$

CODES FOR FIGURE 4.6

Title:Graph of susceptible,Infectious,Recovery against time

clear, clc;

$functionypsir = ypsir(t, y)\ omega = 0.01; mu = 0.86; epsilon = 0.03; pi = 0.62; s = 0.653; p = 0.332; r = 0.2090; N = 1;$

$ypsir(1) = omega - mu * s * p - omega * s;$

$ypsir(2) = mu * s * p + pi * p * r - epsilon * p - omega * p;$

$ypsir(3) = epsilon * p - pi * p * r - omega * r; ypsir = [ypsir(1)ypsir(2)ypsir(3)]';$

$to = 0; tf = 120;$ $yo = [0.960.030.01]$

$[t, y] = ode45('ypsir', [totf], yo);$

$plot(t, y(:, 1),' b', t, y(:, 2),' r', t, y(:, 3),' g')$

$legend('Susceptibles',' Infectives',' Recovery'),$

$ylabel('Totalproportionofpopulation'),$

$xlabel('Time'),$

title('Graph of susceptibles, infectives and Recovery ')

CODES FOR FIGURE 4.7 and 4.8

Title:Graphs of mu =0.44,and mu =0.22 against time respectivel

clear, clc;

function - $ypsir = ypsir(t, y)$ $omega = 0.02; mu = 0.44; andmu = 0.22; epsilon = 0.03; pi = 0.62; s = 0.653; p = 0.332; r = 0.2090; N = 1;$

$ypsir(1) = omega - mu * s * p - omega * s;$

$ypsir(2) = mu * s * p + pi * p * r - epsilon * p - omega * p;$

$ypsir(3) = epsilon * p - pi * p * r - omega * r; ypsir = [ypsir(1)ypsir(2)ypsir(3)]';$

$to = 0; tf = 120;$ $yo = [0.960.030.01]$

$[t, y] = ode45('ypsir', [totf], yo);$

$plot(t, y(:, 1),' b', t, y(:, 2),' r', t, y(:, 3),' g')$

$legend('Susceptibles',' Infectives',' Recovery'),$

$ylabel('Totalproportionofpopulation'),$

$xlabel('Time'),$

title('Graph of susceptibles, infectives and Recovery ')

Appendix C

CODES FOR FIGURE 4.9

Title: Graph of R_0^s against changes in parameters

clear, clc;

$beta = 1 : 0.1 : 2alpha = [0.5]; gamma = [0.5];$

$R_0^s = beta./(alpha + gamma)plot(b, {R_0}^s,' b')$

hold on

$alpha = 1 : 0.1 : 2beta = [1.5]; gamma = [0.5];$

$R_0^s = beta./(alpha + gamma)plot(a, R_0^s,' r')$

hold on

$gamma = 1 : 0.1 : 2beta = [1.6]; alpha = [0.6];$

$R_0^s = beta./(alpha + gamma)plot(g, R_0^s,' g')$

$xlabel('Paramter')$

$ylabel(R_0^s)$

$legend('beta',' alpha',' gamma')$

CODES FOR FIGURE 4.10

Title: Graph of R_0^l against changes in parameters

clear, clc;

$mu = 1 : 0.1 : 2omega = [0.5]; epsilon = [0.5];$

$R_0^s = mu./(omega + epsilon)plot(b, {R_0}^s,' b')$

hold on

$omega = 1 : 0.1 : 2mu = [1.5]; epsilon = [0.5];$

$R_0^l = mu./(omega + epsilon)plot(a, R_0^l,' r')$

hold on

$epsilon = 1 : 0.1 : 2mu = [1.6]; omega = [0.6];$

$R_0^l = mu./(omega + epsilon)plot(g, R_0^l,' g')$

$xlabel('Paramter')$

$ylabel(R_0^l)$

$legend('beta',' alpha',' gamma')$

CODES FOR FIGURE 4.11

Title: Graph of model dynamics

clear, clc;

$functioneuler_method()closeall; clc;$

$h = 0.001;$

$tfinal = 1;$

$sol = [6; 3; 1; 6; 3; 1];$

$m = length(sol);$

$t = 0 : h : tfinal;$

$n = length(t);$

$sol_set = zeros(m, n); sol_set(:, 1) = sol(:);$

$fori = 2 : n$

$fout = model_eqns(sol);$

$sol = sol + h * fout;$

$sol_set(:, i) = sol(:);$

end

$figure(1); holdon;$

$plot(t, (sol_set(1, :)),' r', t, (sol_set(2, :)),' y', t, (sol_set(3, :)),' g', t, (sol_set(4, :)),' b', t, (sol_set(5, :)),' k', t, (sol_set(6, :)),' c')$

$title('ModelDynamics')$

$ylabel('proportionoftotalpopulation')xlabel('Time')$

$legend('Susceptible1',' Prostitute1',' Recovery1',' Susceptible2',' Prostitute2',' Recovery2')$

end

$functionfout = model_eqns(sol)$

$alpha = 0.002; w = 0.002; u = 0.87; beta = 0.87; e = 0.005; gamma = 0.006; c = 0.90; phy = 0.90; m = 0.62; kapa = 0.62;$

$fout = [alpha - beta * sol(1) * sol(3) - alpha * sol(1) - phy * sol(1) * sol(4); beta * sol(1) * sol(3) + kapa * sol(3) * sol(5) - gamma * sol(3) + c * sol(2) * sol(3) - (alpha + c) * sol(3); phy * sol(1) * sol(4) + m * sol(4) * sol(6) + u * sol(2) * sol(4) - e * sol(4) - (w + phy) * sol(4); gamma * sol(3) - kapa * sol(3) * sol(5) - alpha * sol(5); w - w * sol(2) - c * sol(2) * sol(3) - u * sol(2) * sol(4); e * sol(4) - m * sol(4) * sol(6) - w * sol(6)];$

$alpha = 0.001; w = 0.002; u = 0.87; beta = 0.87; e = 0.005; gamma = 0.005; c = 0.96; phy = 0.96; m = 0.62; kapa = 0.62; fout = [alpha - beta * sol(1) * sol(3) - alpha * sol(1) - phy * sol(1) * sol(1);$

$beta * sol(1) * sol(3) + kapa * sol(3) * sol(1) - gamma * sol(3) + c * sol(2) * sol(3) - (alpha + c) * sol(3); gamma * sol(3) - kapa * sol(3) * sol(1) - alpha * sol(1); w - w * sol(4) - c * sol(4) * sol(5) - u * sol(4) * sol(5); phy * sol(4) * sol(5) + m * sol(5) * sol(6) + u * sol(4) * sol(5) - e * sol(5) - (w + phy) * sol(6); e * sol(4) - m * sol(5) * sol(6) - w * sol(6)]; end$

CODES FOR FIGURE 4.12

Title: Graph of model dynamics on student

clear, clc;

$functioneuler_method()$

$closeall; clc;$

$h = 0.001;$

$tfinal = 1sol = [6; 3; 1];$

$m = length(sol);$

$t = 0 : h : tfinal;$

$n = length(t);$

$sol_set = zeros(m, n);\ sol_set(:, 1) = sol(:);$

$fori = 2 : n$

$fout = model_eqns(sol);$

$sol = sol + h * fout;$

$sol_set(:, i) = sol(:);$

end

$figure(1); holdon;$

$plot(t, (sol_set(1, :)),' r', t, (sol_set(2, :)),' y', t, (sol_set(3, :)),' g')title('ModelDynamicsonfemalestu$

$ylabel('proportionofpopulation')$

$xlabel('Time')$

$legend('Susceptible1',' Prostitute1',' Recovery1')$

end

$functionfout = model_eqns(sol)$

$alpha = 0.002; w = 0.002; u = 0.87; beta = 0.87; e = 0.005; gamma = 0.006; c = 0.90; phy = 0.90; m = 0.62; kapa = 0.62;$

$fout = [alpha - beta * sol(1) * sol(3) - alpha * sol(1) - phy * sol(1) * sol(4); beta * sol(1) * sol(3) + kapa * sol(3) * sol(5) - gamma * sol(3) + c * sol(2) * sol(3) - (alpha + c) * sol(3); phy * sol(1) * sol(4) + m * sol(4) * sol(6) + u * sol(2) * sol(4) - e * sol(4) - (w + phy) * sol(4); gamma * sol(3) - kapa * sol(3) * sol(5) - alpha * sol(5); w - w * sol(2) - c * sol(2) * sol(3) - u * sol(2) * sol(4); e * sol(4) - m * sol(4) * sol(6) - w * sol(6)];$

$alpha = 0.001; w = 0.002; u = 0.87; beta = 0.87; e = 0.005; gamma = 0.005; c = 0.96; phy = 0.96; m = 0.62; kapa = 0.62$

$; fout = [alpha - beta * sol(1) * sol(3) - alpha * sol(1) - phy * sol(1) * sol(1); beta * sol(1) * sol(3) + kapa * sol(3) * sol(1) - gamma * sol(3) + c * sol(2) * sol(3) - (alpha + c) * sol(3); gamma * sol(3) - kapa * sol(3) * sol(1) - alpha * sol(1)];$

end

CODES FOR FIGURE 4.13

Title: Graph of model dynamics on lecturer

clear, clc;

$functioneuler_method()$

$closeall; clc;$

$h = 0.001;$

$tfinal = 1sol = [6; 3; 1];$

$m = length(sol);$

$t = 0 : h : tfinal;$

$n = length(t);$

$sol_set = zeros(m, n);$ $sol_set(:, 1) = sol(:);$

$fori = 2 : n$

$fout = model_eqns(sol);$

$sol = sol + h * fout;$

$sol_set(:, i) = sol(:);$

end

$figure(1); holdon;$

$plot(t, (sol_set(1, :)),'b', t, (sol_set(2, :)),'k', t, (sol_set(3, :)),'c')title('ModelDynamicsonmalelectu$

$ylabel('proportionofpopulation')$

$xlabel('Time')$

$legend('Susceptible2','Prostitute2','Recovery2')$

end

$functionfout = model_eqns(sol)$

$alpha = 0.002; w = 0.002; u = 0.87; beta = 0.87; e = 0.005; gamma = 0.006; c = 0.90; phy = 0.90; m = 0.62; kapa = 0.62;$

$fout = [alpha - beta * sol(1) * sol(3) - alpha * sol(1) - phy * sol(1) * sol(4); beta * sol(1) * sol(3) + kapa * sol(3) * sol(5) - gamma * sol(3) + c * sol(2) * sol(3) - (alpha + c) * sol(3); phy * sol(1) * sol(4) + m * sol(4) * sol(6) + u * sol(2) * sol(4) - e * sol(4) - (w + phy) * sol(4); gamma * sol(3) - kapa * sol(3) * sol(5) - alpha * sol(5); w - w * sol(2) - c * sol(2) * sol(3) - u * sol(2) * sol(4); e * sol(4) - m * sol(4) * sol(6) - w * sol(6)];$

$alpha = 0.001; w = 0.002; u = 0.87; beta = 0.87; e = 0.005; gamma = 0.005; c =$

$0.96; phy = 0.96; m = 0.62; kapa = 0.62$

$; fout = [alpha - beta * sol(1) * sol(3) - alpha * sol(1) - phy * sol(1) * sol(1); beta * sol(1) * sol(3) + kapa * sol(3) * sol(1) - gamma * sol(3) + c * sol(2) * sol(3) - (alpha + c) * sol(3); gamma * sol(3) - kapa * sol(3) * sol(1) - alpha * sol(1)];$

end