



How to control the immigration of infectious individuals for a region?



Hebai Chen^a, Lan Zou^{b,*}

^a College of Mathematics and Computer Science, Fuzhou University, Fuzhou, Fujian 350002, China

^b Department of Mathematics, Sichuan University, Chengdu 610064, China

ARTICLE INFO

Article history:

Received 13 December 2017

Received in revised form 25 May 2018

Accepted 13 July 2018

Keywords:

Immigration
Switching system
Sliding set
Closed orbit
Global dynamics

ABSTRACT

Immigration has contributed to the increase of certain infectious diseases in some regions. To inspect the impact of controlling immigration of infectious individuals on the transmission of infectious diseases in a region, we construct a basic SIR model with switching imported infectious population. There is no disease-free equilibrium and no basic reproduction number for this system. Based on the global dynamical analysis for the switching system, we know that a proper control of immigration of infectious individuals can control the infectious population for a region at a certain low level.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

It is more and more common to travel and immigrate around the world. Globally, there were 244 million international migrants in 2015 [1]. In China, the migrant population including internal migration and international migration was 245 million in 2016 [2]. Human movement is believed to be important for the epidemiology of diseases including vector-borne diseases [3]. Immigration of infected individuals has taken lots of interests in epidemic models, such as [4–8]. Several SI, SIS and SIR models with immigration of infections were studied in [4]. A model with immigration of exposed individuals was considered in [5]. In [6], the SEI model included immigration into all groups. The disease dynamics for the hometown of migrant workers was discussed in [7].

In recent researches, piecewise systems have been applied to epidemical dynamical models [9–13], to describe the discontinuous terms including the infection incidence, the vaccination, as well as treatment. Xiao et al. studied the non-smooth incidence which is expressed in piecewise smooth function for media coverage in [13]. Tang et al. constructed a compartmental SIRS model with seasonal succession by a periodic

* Corresponding author.

E-mail address: lanzou@163.com (L. Zou).

discontinuous differential system [9]. Switching vaccination strategy was considered in a SIV model in [10]. More work focused on non-smooth treatment. For example, [12] used a switching system with the treatment

$$T(I) = \begin{cases} k, & \text{if } I > 0, \\ 0, & \text{if } I = 0, \end{cases}$$

and Wang [11] proposed a piecewise linear treatment function

$$T(I) = \begin{cases} kI, & \text{if } 0 \leq I \leq I_{crit}, \\ kI_{crit}, & \text{if } I > I_{crit}. \end{cases}$$

In some regions, certain diseases are screened when people enter and those infectious travelers are isolated so that they will not contact others. It is a useful step to control the spread of an infectious disease from one region to another. Some successful examples are found, such as SARS. It is effective to inspect through entry screening and isolate the infectious individuals. However, it is not practical to do it for every infectious disease because of the great cost. In fact, such measure is only necessary for those infectious diseases which are endemic. When shall we do it? Our aim of this paper is to discuss the impact of controlling the import infectious population, and to search a best control threshold I_{crit} .

Different from the previous models with immigration [4–7], we construct a piecewise smooth system. On the other hand, because of the immigration term in the model, there are no disease free equilibria in our model. Thus, the basic reproduction number cannot be given like other epidemical models with piecewise smooth functions [9–13]. We concentrate on the global analysis of the model, and discuss the controlling threshold of the imported infectious individuals I_{crit} based on different locations and stabilities of disease endemic equilibria.

The rest of the paper is organized as follows. A SIR model with switched import infectious is constructed in Section 2. In Section 3, the existence and qualitative properties of equilibria of system (2.3) are discussed. In Section 4, we prove the non-existence of closed orbits and therefore obtain the global phase portraits of the system. Numerical examples and simulations are shown in Section 5 to verify our results.

2. The model

We consider the most classical SIR compartmental model and divide the population into three classes: susceptible S , infectious I and recovered R . An individual in any compartmental group can travel. Suppose A is the recruitment through birth and immigration into susceptible population, C is the immigration into recovered population. For simplicity, let us suppose that $A, C \geq 0$ are constants. When the imported infectious individuals are isolated, they cannot contact the susceptible individuals, and there is no imported infectious. Let $B(I)$ be the immigration into infectious population, and $B(I)$ is a function of I given by

$$B(I) = \begin{cases} B_{crit}, & I < I_{crit}, \\ 0, & I \geq I_{crit}, \end{cases}$$

where $B_{crit}, I_{crit} > 0$ are constants. That is, when I is small enough, the entry screening measure is not implemented, and people do not control the import of infectives. However, as I becomes large, we have to control and keep from the import of infections. For example, when I is large, we screen the travelers entering the region, and isolate the infections, so that they cannot transmit the disease to the susceptible individuals. Let βSI be the bilinear incidence rate, where $\beta > 0$ is the transmission coefficient. Furthermore, denote γ as the recovery rate of infections, and μ as the mortality rate.

The model is given by the following system:

$$\begin{cases} \frac{dS}{dt} = A - \beta SI - \mu S, \\ \frac{dI}{dt} = B(I) + \beta SI - \mu I - \gamma I, \\ \frac{dR}{dt} = C + \gamma I + \mu R. \end{cases} \quad (2.1)$$

Download English Version:

<https://daneshyari.com/en/article/7221877>

Download Persian Version:

<https://daneshyari.com/article/7221877>

[Daneshyari.com](https://daneshyari.com)