THE DEVELOPMENT AND EVALUATION OF MATHEMATICAL MODELS FOR THE SPREAD OF POLITICAL FIGURE VOTERS WITH APPLICATION TO PRESIDENTIAL ELECTIONS IN INDONESIA

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ABSTRACT

The aims of this study were to develop and evaluate the mathematical models for the spread of political figure fever in presidential elections in Indonesia. This thesis introduced several new models concerning the analysis of the spread of voters by showing modeling and simulation. The methodology is based on quantitative research using epidemiological approach. This study employed four different types of continuous time deterministic models; $SIR, SIRS, SI_1I_2R$, and SI_1I_2RS. These new models were applied to the presidential elections data in Indonesia to analyze the dynamical spread of voters of presidential candidates. The analysis of the result were displayed in the graph to show dynamical change on each individual. Simulations performed to obtain an overview of the dynamics of the spread of the influence of voters in the population. The results comparing the simulations for these models showed the best model for estimating the number of votes is SI_1I_2RS model. Furthermore, from simulations it can be seen how quickly changes occur with regard to the values of the parameters that obtained from various sources. The results also showed that to increase the number of votes, the political parties or political figures should consider the factor of media and boredom rate. The presence of media will increase the spread of political figure fever among voters. Positive media will increase the number of political figure voters, otherwise negative media will decrease the number of political figure voters. The study also concludes that the boredom rate is one of the sensitive parameters in the political figure fever model. The higher the boredom rate between voter populations, the more serious attention of political figure is needed. As a conclusion, this study succeeds to develop and evaluate new mathematical models using epidemiological approach. The implication of the study is that these mathematical models could be used to assist political parties or political figures in making the strategy to increase their supporters by estimating the number of votes of both cases; absence and presence of media. The results displayed in voters map can be used to identify which area has the highest number of voters, which area with the lowest number of voters, or which area need further attention to increase the number of voters.

PEMBINAAN DAN PENILAIAN MODEL MATEMATIK BAGI TEBARAN PENGUNDI TOKOH POLITIK DENGAN APLIKASI TERHADAP DATA PILIHAN RAYA PRESIDEN DI INDONESIA

ABSTRAK

Kajian ini bertujuan membina dan menilai model matematik untuk tebaran pengundi tokoh politik dalam demam pilihan raya presiden di Indonesia. Kajian ini memperkenalkan beberapa model baharu bagi menganalisis tebaran pengundi dengan menunjukkan kaedah pemodelan dan simulasi. Kaedah kuantitatif dengan pendekatan epidemiologi digunakan dalam kajian ini yang melibatkan empat jenis model matematik. Model-model matematik berketentuan masa selanjar yang digunakan ialah $SIR, SIRS, SI_1I_2R$, dan SI_1I_2RS. Model-model baharu ini diaplikasikan pada data pilihan raya presiden di Indonesia untuk menganalisis tebaran dinamik pengundi calon presiden. Seterusnya, analisis keputusan dipaparkan dalam graf untuk menunjukkan perubahan dinamik pada setiap individu. Simulasi dilaksanakan untuk mendapatkan gambaran keseluruhan tebaran dinamik pengaruh pengundi dalam kalangan penduduk. Dapatan kajian menunjukkan bahawa model terbaik untuk menganggarkan jumlah undi berdasarkan media ialah model SI_1I_2RS. Seterusnya, daripada simulasi dapat dilihat sepantas manakah berlakunya perubahan yang berkait dengan nilai parameter yang diperoleh daripada pelbagai sumber. Keputusan juga menunjukkan bahawa untuk meningkatkan jumlah undi, parti atau tokoh politik patut mengambil kira faktor media dan kadar kebosanan. Kehadiran media berpotensi untuk meningkatkan pengaruh tokoh politik dalam kalangan pengundi. Liputan media yang positif boleh meningkatkan bilangan pengundi bagi seseorang tokoh politik, manakala liputan media yang negatif boleh mengurangkan bilangan pengundi seseorang tokoh politik. Kadar kebosanan ialah salah satu parameter sensitif dalam model untuk tokoh politik dalam demam pilihan raya presiden. Semakin tinggi kadar kebosanan dalam populasi pengundi, semakin serius perhatian yang diperlukan oleh tokoh politik. Kesimpulannya, kajian ini berjaya membangunkan dan menilai model matematik baharu melalui pendekatan epidemiologi. Model matematik ini dapat digunakan untuk membantu parti atau tokoh politik dalam merangka strategi untuk meningkatkan penyokong mereka dengan menganggarkan jumlah undi dalam kedua-dua kes, iaitu ketika ketiadaan dan kehadiran media. Implikasinya, keputusan yang dipaparkan dalam peta pengundi boleh digunakan untuk mengenal pasti kawasan dengan bilangan pengundi terbanyak, kawasan dengan bilangan pengundi terendah, atau kawasan yang memerlukan perhatian lebih lanjut untuk meningkatkan bilangan pengundi.

TABLE OF CONTENTS

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 RESEARCH METHODOLOGY

CHAPTER 4 FINDINGS AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

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LIST OF APPENDICES

LIST OF ABBREVIATIONS

ODE	Ordinary differential equation
PEMILU	Pemilihan umum
SI	Susceptible – Infected
SIS	Susceptible – Infected – Susceptible
SIR	Susceptible – Infected – Recovered
$SIRS$	Susceptible – Infected – Recovered – Susceptible
SI_1I_2R	Susceptible – Infected 1 – Infected 2 – Recovered
SI_1I_2RS	Susceptible – Infected 1 – Infected 2 – Recovered – Susceptible
$SIVR$	Susceptible – Infected – Vaccinated – Recovered
$SEIR$	Susceptible – Exposed – Infected – Recovered
$SEIRS$	Susceptible – Exposed – Infected – Recovered – Susceptible
SMR	Standardized Mortality/Morbidity Ratio
SIR	Standardized Incidence Ratio
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

The first general elections (PEMILU) in Indonesia was held in 1955. This elections is indirect elections because voters elect the political parties, which then elects the president. The president is elected for a five-year term. The voters are Indonesian citizens and the minimum voting age is 17; however, persons under 17 who are married at the time of registration are allowed to vote. Direct general elections has been held twice in Indonesia, which are in 2004 and 2009. The third direct Indonesian presidential elections already being held in July 9, 2014.

Candidates for president will be nominated as individuals (along with a vice-presidential running partner). However, support from the main political parties are likely to play a key role in influencing the result. Partly for this reason, the highly changeable map of political parties in Indonesia contributes to the uncertainty of political trends during 2013 and into 2014 in the run-up to the presidential elections. In recent years, the number of political parties contesting major elections (both elections for the national and regional parliaments, and the presidential elections) has varied considerably. In 2004, 24 parties contested the national elections and 16 secured enough seats to be represented in the national parliament. In 2009, 38 parties contested the national elections and 9 secured enough seats to be represented in the national parliament. In 2014, 12 parties will contest the national elections. It is expected that candidates for president who hope to mount an effective campaign will need to secure the support of at least one of the major parties as well as several other smaller parties.

The popularity of presidential candidate influenced by exposure from TV, radio, newspaper, or social media (Mujani & Liddle, 2013). Jakarta Governor Joko Widodo tops the list of Google's most trending people in Indonesia for 2012. In spite of his public assertion that he will not run in the 2014 presidential elections, Joko Widodo (Jokowi) has become Indonesia's most popular presidential possibility due to the negative media coverage of most established political parties (Saragih, 2013). Currently in Indonesia, Jokowi is one of the most influencial figure ("infectious") for the presidential elections in 2014.

In this study, mathematical models are used to describe the behavior of a system. Mathematical models have been widely used in various areas (Tu, 1992; Strogatz, 2001; and Takeuchi, 2007). Mathematical models are used, particularly not only in the natural sciences and engineering disciplines such as physics, biology, and electrical engineering, but also in the social sciences such as political science, as published in Peterson (1991), Belenky and King (2007), and Nagel (2010). Mathematical modelling is the use of mathematics to describe real-world phenomena, investigate important questions about the observed world, explain real-world phenomena, and make predictions about the real world. Mathematical models are used for comparing, planning, implementing, evaluating, optimizing various detection, and control programs. There is no best model, only better models.

Mathematical models have become important tools in analyzing the spread and control of infectious diseases and plans for defense against disease attacks, especially when combined with powerful, modern computer methods for analyzing and/or simulating the models (Daley, 1999; Allman & Rhodes, 2004; Bailey et al., 2005; Keeling & Rohani, 2007; and Vynnycky & White, 2010). Mathematical models can sharpen our understanding of fundamental processes, compare alternative policies and interventions, help make decisions, prepare responses to disease attacks, provide a guide for training exercises and scenario development, guide risk assessment, and predict future trends (Chitnis et al., 2008).

Many dynamical social phenomenon were modelled by using the epidemiological type differential equations (Kawachi, 2008). Kermack and McKendrick in 1927 proposed the first SIR epidemic model (Kermack & McKendrick, 1927). Since this simple model, there have been many researchers that have numerically and analytically analyzed infectious disease model. Furthermore, many studies have developed more complex model and these models are applied to another field, for example in politics. However, mathematical research in politics especially about political figure fever using epidemiological approach is scarce. A simple mathematical model for the spread of two political parties was discussed in Misra (2012), an epidemiological approach to the spread of political third parties was discussed in Romero et al. (2011), and stability of equilibria in multi-party political system was discussed in Peterson (1991).

Many studies have developed these models, for example in Khan (2000), where he investigated these model related with time delay. However, only a few researcher that study these models related to basic reproductive number. These research discuss mathematical models in politics by through epidemiological approach in related to political parties, not to political figure. There is a study that discuss a mathematical model related to artist, for example in Tweedle and Smith (2012), they develop a mathematical model to describe the spread of Bieber fever. In this research, mathematical models for the spread of voters of political figures fever such as Jokowi in the Indonesian general elections will be studied. We propose some new deterministic models to understand the spread of voters in political figures fever in a closed population. From these models, the dynamics of the spread of voters in

each population can be known. The dynamical analysis is used for analyzing the behavior of the spread of this fever.

1.2 Problem Statement

The presidential candidates who will be standing in elections should try to get as much support among the voters. The problem is what kind of mathematical models which can explain a situation that describes it. Many studies focus on political parties for knowing the dynamical change of voters, for example in study by Peterson (1991) and Khan (2000). Currently, there is no study focus on political figure fever for knowing the dynamical spread of voters of political figure. In some countries with a direct presidential elections like in America and Indonesia, a political figure is one of the most important things must be considered by political parties, because the political figure can convince people to choose the political figure such that the political figure has the highest level of position in the elections. In this study, a political figure fever model for the spread of voters in elections in Indonesia will be constructed using epidemiological approach, following the *SIR* model, and then the stability of equilibrium points that exist in the model will be analyzed. Basic reproductive number also will be determined. Then, the model will be modified in order to obtain a better model. In addition, numerical simulations will be presented to the models of all the political figures. From simulation, the performance of political figures will be

compared each other so that political parties can determine the next strategy for their candidates to reach the maximum voters.

One common mathematical model in epidemiology is the *SIR* model, which consists of a system of three differential equations that describe the changes in the number of susceptible, infectious/infected, and recovered/removed individuals in a given population. Susceptibles (S) are individuals in the population who have not been infected, but are at risk, infectious/infected (I) are individuals who are figure-infected and are capable of affecting (transmitting something to) someone, and recovered/removed (R) are individuals who are "immune" to infection, for example those who have lost interest in a figure, but "immunity" can be lost (Tweedle & Smith, 2012). Individuals enter the susceptible population by a given recruitment rate. They can become infected by contact with individuals infected or through media, like social media (Facebook and Twitter), newspaper, magazine, TV, radio, etc. Media can affect the flow of individuals between compartments (Tchuenche et al., 2011). Susceptible can become bored of political figures and this population will be moved to recovered population. Infected individuals can recover by losing interest in political figures at a boredom rate.

Therefore, we are interested to construct and analyze the models of political figures fever, specifically for presidential elections in Indonesia. The dynamical model is formulated to describe the spread of this fever. Here, we give the numerical results to describe the dynamics of each voter population and to confirm our analytical results.

1.3 Research Framework

This study utilized the quantitative research using epidemiological approach in order to achieve the purpose of the study, which is to describe how modeling and simulation could be used to assist political parties or political figures in making the strategy by estimating the number of votes of such models to increase their votes in elections. The research framework for this thesis is shown in Figure 1.1.

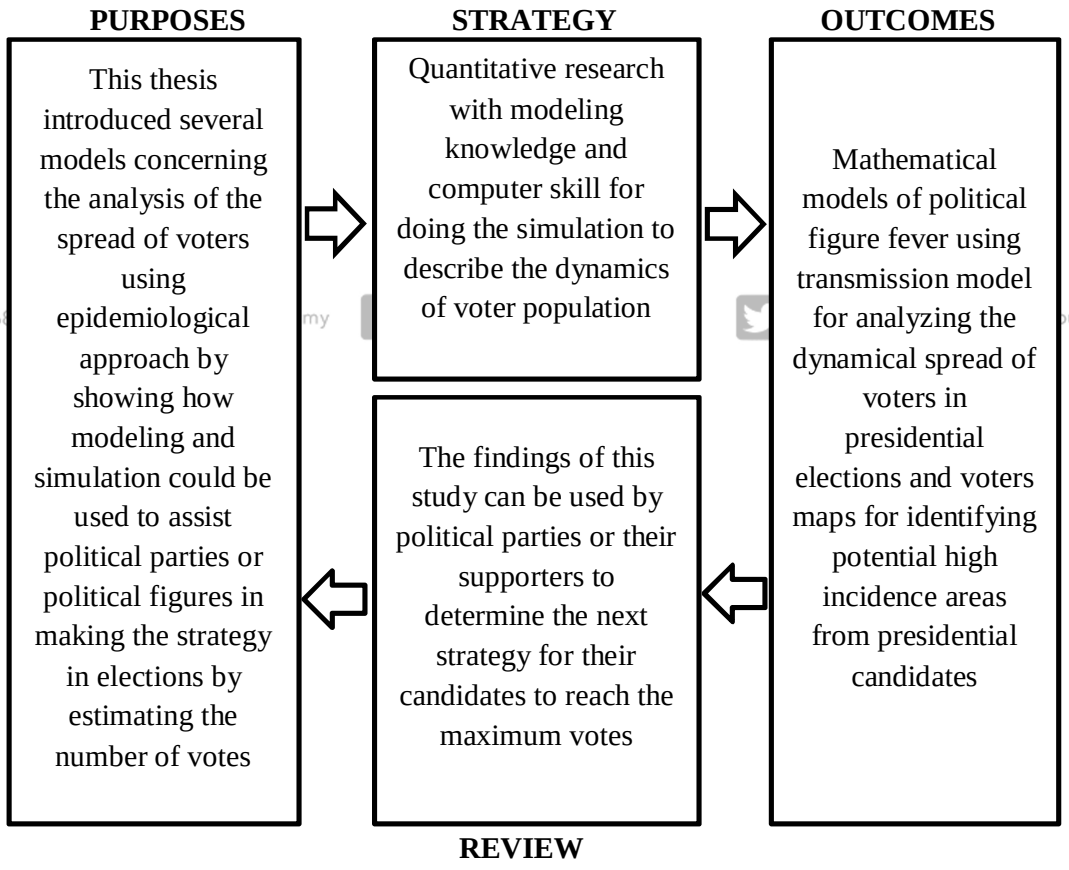

Figure 1.1. Research framework of the thesis

1.4 Objectives of the Research

Main object of this thesis is a mathematical model for the spread of voters in case of presidential elections in Indonesia. Following are the objectives of this study:

1. To introduce a new continuous time based on SIR model for political figure fever transmission
2. To estimate basic reproductive number of political figure fever using data of general elections in Indonesia
3. To investigate how much influence of media coverage in the population, especially social media
4. To propose new models of political figure fever hat considered two figures
5. To compare the result of estimated number of votes for political figures based on $SIR, SIRS, SI_1I_2R$, and SI_1I_2RS models
6. To estimate the relative potential votes for voters mapping based on standardized incidence ratio method for the spread of voters transmission in Indonesian presidential elections
7. To propose the distribution of voters map in the study of political figure fever in case of presidential elections in Indonesia

1.5 Significance of the Research

This research is concerned about the political figure fever model in Indonesia. From the solution of the model, we can describe the condition of political atmosphere

before elections, so that political parties can make strategies based on analysis of this model in increasing number of votes for their candidates on the elections. Result of voters mapping can be used by presidential candidates or political parties that support their presidential candidates to identify which area has the highest number of voters, which area with the lowest number of voters, or which areas need further attention to increase the number of votes.

The following section contains an outline of the thesis. The section gives an overview of the work that it contains.

1.6 Thesis Outline

This thesis is organized into five chapters. Chapter 1 introduces the background and motivation of the study and the problem statement. Then, the objectives for this study are explained. This thesis also includes the significance of the research.

Chapter 2 gives a brief explanation about the general elections in Indonesia, especially presidential elections in Indonesia. This chapter also review about theoretical concept of modeling and analysis of deterministic transmission model using epidemiological approach including differential equation and system of differential equations, critical points and Jacobian matrix, eigenvalues, types of stability, Routh-Hurwitz stability criterion, and basic reproductive number.

Chapter 3 presents and explains the methodology of the research. This includes the description of deterministic nonlinear differential equations for the transmission models of the spread of political figure fever with and without media; $SIR, SIRS, SI_1I_2R$, and SI_1I_2RS. This chapter also defines the parameters of the models that we proposed. Finally, the study of voters mapping using the Standardized Incidence Ratio method is also explained in this chapter.

In Chapter 4, analysis of the transmission models for the spread of political figure fever is discussed. We give the analytical solutions and present the numerical simulations of the models proposed in Chapter 3. This chapter also investigates effect of (social) media on the political figure fever model. In the last section, we presents and demonstrates the results of our application to relative potential votes estimation for voters mapping to observed presidential elections data from Indonesia. This includes the results of relative potential votes estimation based on standardized incidence ratio method. All related findings are then compared and presented in tables, figures, and maps.

Finally, Chapter 5 summarises the findings of the study. It presents the conclusions, expected contributions, and some recommendations for future works of the thesis.

CHAPTER 2

LITERATURE REVIEW

This chapter is divided into two main sections. First section briefly describe about presidential elections in Indonesia. Second section discusses about previous studies related to the modelling and analysis of population dynamics using epidemiological approach.

2.1 Presidential Elections in Indonesia

Direct general elections has been held twice in Indonesia, which are in 2004 and 2009. Year 2014 is the third time direct general elections in Indonesia. Legislative elections at national and regional level has been held on 9th April 2014 and presidential elections was held on 9th July 2014 with campaign period for nominated president in two months, May and June.

In terms of number of voters, elections in Indonesia considered as the second highest in the world after United States. Based on census 2010, total population in Indonesia is 237.56 million poeple. Currently, total Indonesian people are 253,609,643 and total voters until 4th November 2013 is 186,610,000 people. Based on a survey before parliamentary elections, Jokowi gains 30% of the votes. The requirement of voters at least 17th years old (at the time on elections) or any ages for who has been married. Permanent voters register (DPT) for general elections in 2014 has been announced since 4th November 2013, with 186.61 million voters. At elections in year 2009 with 171 million registered voters, meanwhile only 122 million voters (71%) use their right in elections.

President is the highest position leader at executive level, which can be elected/choosen maximum two times with five years each period. The parliamentary elections is of strategic importance for the presidential elections as a minimum of 25% of the popular vote in the legislative elections (or 20% of seats in the House of Representatives (DPR)) gives the political party or coalition party the authority to

nominate a presidential candidate (Schaar, 2014). Presidential elections can be held after legislative elections, the purpose is to fulfil all requirement above in proposing president name. President and vice president will be choosen directly by poeple. Current president, Susilo Bambang Yudhoyono is president who has been proposed by Democratic Party (PD). He has been choosen for the second time and as the last time when the first cycle in year 2009 elections achieved 60.8% from total votes. If the candidates failed to achieve the highest votes in the first cycle, therefore should be held the second cycle elections in September 2014. The choosen president will be appointed in October 2014.

Indonesia used multyparties system. In 2014 presidential elections, Indonesia has 46 registered parties, but only twelve national parties and in additional three local political parties can be chosen in Aceh province only. The twelve national political parties are National Democratic Party (NASDEM), National Awakening Party (PKB), Prosperous Justice Party (PKS), Indonesian Democratic Party of Struggle (PDI-P), Party of the Functional Groups (Golkar), Great Indonesia Movement Party (Gerindra), Democratic Party (PD), National Mandate Party (PAN), United Development Party (PPP), People's Conscience Party (Hanura), Crescent Star Party (PBB), and Indonesian Justice and Unity Party (PKPI). Three political parties in Aceh are Aceh Peace Party (PDA), Aceh National Party (PNA), and Aceh Party (PA). A presidential candidate need to be supported by political parties.

Based on survey from January 2013 – February 2014, founded two candidates for President 2014, there are Joko Widodo and Prabowo Subianto. Joko Widodo