MODELLING DYNAMICS OF VICTIMS' STRESS DURING NATURAL DISASTER

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Abstrak

Bencana alam merupakan fenomena alam yang menyumbang kepada pembentukkan masalah psikologi kepada kebanyakkan individu. Tekanan psikologi adalah salah satu kesan akibat daripada bencana ini dan ianya merupakan realiti sebenar dimana kesan daripada persekitaran luar yang menyebabkan individu mengalami tekanan yang akan lambat laun boleh membawa kepada masalah psikologi. Dalam bidang pengkomputan psikologi, pemodelan komputasi telah digunakan sebagai alat untuk memahami corak fungsi kognitif dan tingkahlaku manusia. Manakala, teori-teori psikologi dan kognitif serta bukti empirikal adalah berguna dalam menyediakan asas yang kukuh mengenai faktor serta atribut yang menyebabkan tekanan psikologi untuk mangsa banjir sewaktu bencana alam itu berlaku. Oleh itu, kajian ini telah menggunakan model formal (model komputasi) dalam memahami keadaan semasa tekanan perasaan mangsa bencana alam. Dengan menggunakan teori yang berkaitan, terdapat 22 faktor asas telah dapat dikenalpasti dan dikelaskan kepada 7 kategori utama termasuk faktor kecenderungan, sumber, atribut individu, penilaian, kebingkasan, keupayaan bertahan, dan tekanan. Faktor ini telah dapat memberikan pengetahuan asas terhadap tingkahlaku mangsa sewaktu bencana alam berlaku. Satu model formal telah telah dibangunkan dengan menggunakan kaedah persamaan pembezaan. Selepas itu, model ini telah disimulasikan berdasarkan senario yang berkaitan seperti; 1) mangsa dengan tahap tekanan yang rendah, 2) mangsa dengan tahap tekanan yang sederhana, dan 3) mangsa dengan tahap tekanan yang tinggi dengan menggunakan bahasa pengaturcaraan Matlab. Model komputasi ini telah disahkan dengan menggunakan dua teknik; 1) penentusahan logikal (*Temporal Trace Language*) dan 2) penentusahan matematik (analisis kestabilan). Hasil eksperimen telah berjaya menerangkan secara anggaran mengapa mangsa mengalami masalah tekanan dalam keadaan yang berbeza sewaktu bencana alam berlaku.

Abstract

Natural disaster is one of the inescapable phenomenon through which numerous number of individuals are being affected via developing psychological problems. Stress is one of the essential psychological effects of natural disaster; it is a reality of nature where forces from the outside world affect individuals exposed to such phenomenon. In computational psychology domains, computational models were used as tools for understanding human cognitive functions and behavioural patterns. Meanwhile, psychological and cognitive theories as well as empirical studies have provided convergent evidence to identify important factors and psychological attributes that affect the stress level of victims during natural disaster. Therefore, this study implements a formal model (computational model) to understand the current state of victims' stress during natural disaster. From related theories, 22 of basic factors have been established and grouped into 7 main categories that include predisposed factors, resources, individual attributes, appraisal, resilience, coping, and stress. Those factors provide the fundamental knowledge of the behaviours of victims after disaster occurrence. A formal model was developed by using a set of differential equations. Later, this model was simulated by applying related scenarios based on three different cases, namely; 1) a good victim with low level of stress, 2) victim with high level of stress, and 3) victim with moderate level of stress) through the use of Matlab as a programming language. This computational model was then verified using two techniques; 1) logical verification (Temporal Trace Language) and 2) mathematical verification (stability analysis). The experimental results have approximately predicted why victims develop stress differently when facing natural disasters.

Acknowledgement

All praises and thanks is due to Almighty Allah, the most gracious and the most merciful for lightening my way throughout the completion of this valuable thesis. I adore His benevolence and mercy, without his kindness, I will not be able to complete this study especially as i was thousand miles away from my beloved country (Iraq). Also, my sincere appreciation goes to Dr. Azizi Ab Aziz., the busiest person i have ever met, yet always ready to assist whenever the path seem uneasy. Though, fully occupied but ready to push me out of any difficulties during the course of my study. In addition, I would like to thank Associate Professor Dr.Faudziah Ahmad, the co-supervisor who treated me like her son.

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CHAPTER ONE

INTRODUCTION

This chapter briefly explains the background of the study, problem statement, research questions, objectives, significance and scope of the study.

1.1 Background

Each society and its parts (e.g., individuals, groups, organizations, communities, etc.) are frequently and occasionally in an unexpected manner to exposed to disasters, whether a disaster happened through technological failure or industrial mistakes (such as explosion, widespread power outages, and structure collapse) or as a natural phenomenon (e.g., flood , earthquakes ,and landslides), or by virtue of human-making (e.g., terrorism and riots), or hybrid disasters (e.g., the setting of residential zones, factories, at the foot of an active volcano, or in an avalanche area). The normal settings of a society and its components will be affected in a more or less serious manner. Disasters are specific form of stressor in that they impact wide areas of population at once and may be accompanied by a large number of possible harmful outcomes such as mass casualties, displacement, and property damage (Norris, 2002). In addition, survivors may be exposed to secondary hazards, for instance, in the case of hurricane Katrina, the damage of the oil facilities by the hurricane caused the hazardous materials to be exposed into the environment. A disaster whether through natural events such as hurricane Katrina or human-making like terrorism, example the 9/11 attack on the World Trade Centre in 2001 could cause a huge impact to both physical and humans entities. Thus, many studies have been conducted to evaluate the economic impacts by estimating possible losses to predict potential effects of a disaster in advance (Garrett, 2005; Karesh & Cook, 2005; Mileti, 1999). Natural disasters without doubts have a profound influence on the quality of life through their devastating effects on livestock and food crops, and forced displacement of households and communities. According to (Guha-Sapir, Hargitt, & Hoyois, 2004), an average of 255 million people were affected worldwide each year as a result of natural disasters in the past 30 years between 1973 and 2003. Their involvement on lives and the instant poverty loss are among the most distressing effects (UNESCAP, 2007).

The tragedy of natural disasters on livelihoods gave rise to widespread trauma and distress pushing countries to the need for national level strategies for disaster prevention, recognition, and preparedness. Moreover, natural disasters such as tsunami, earthquakes, and flood are some of the causal factors to high level of psychological problems and stress in individuals. Physical effects such as loss and destruction of properties and life are among many consequences of natural disasters. These impacts may be for short or long term. During the short-term period, victims often make hard efforts to accept and cope with these unhelpful effects. As a result, many organizations such as the World Health Organization worried about the health of victims of natural disasters. In the recent years much attention among scientists had shown the relation between natural disaster and mental and physical health (Enarson, 2012; Wahlström, Michélsen, Schulman, & Backheden, 2013). Many researchers (Gros et al., 2012; Nasir, Zainah, & Khairudin, 2012; Tuicomepee & Romano, 2012) illustrated that there is relationship between psychological problems and the disasters among different group of people who are directly involved in disasters (e.g. victims and as well, the volunteers involved in rescuing them). Despite all these claim, people still developed acute stress instantaneously, and this spells out the aftermath of a disaster that is virtually universal and normative (Foa, Stein, &McFarlane, 2006). Researches in natural disaster have shown that 39 percent of disaster victims report severe, to very severe post-traumatic stress disorder (PTSD)(Gros et al., 2012; Norris, Friedman, Watson, et al., 2002). This is the maladaptive effect of disasters for the long-term period. Partially, distress of survivors during natural disaster may come from number of injuries and fatalities, as well as damages to infrastructures (e.g., roads, transportation, communications, and hospital systems), survivors may be separated from their families and loved ones.

In the context of Malaysia, floods and landslides are two most common natural disasters. In February 2011, the southern state of Johor was overwhelmed by floods. The sudden recurrence after a lapse of four years took the residents by shock, thereby given rise to loss of life and properties. The cost of damage arising from the disaster worth millions, and a lot of people were traumatized by the flood (Azmi, Hashim, & Zamhury, 2012). With regards to Malaysia, flood can be classified into three categories, namely flash flood, tropical flood and monsoon flood. However, monsoon flood is the most suffered flood in Malaysia caused by the effect of continent location and sea water level which affected states such as Johor, Pahang, Perils, Terengganu, Sabah dam Sarawak (Liu, Xie, Tang, & Timothy, 2005).

Generally flood happens in east-coast states of Kelantan, Pahang, and Terengganu because of the effect of monsoon. Moreover, states such as Kedah, Melaka, Pulau Pinang, Perak, and Selangor have witnessed flash floods, in 2010 and these flash floods turned into a nightmare when it became natural disaster and affected area that had never suffered flooding before (Johari & Marzuki, 2013). Thus, based on the above, it can be seen that there is significant number of people suffering from natural disasters and this can influence the development of psychological problems such as stress for short-term period (roughly, one or two weeks). However, there is always a portion who experience long-term distress (Wahlström, Michélsen, Schulman, & Backheden, 2008).

However, there is need to develop mechanism that can monitor the conditions of victims who are facing the psychological effects of natural disaster which will eventually improve their quality of life. In order to achieve this, understanding victims with natural disaster and understanding symptoms and its development in a person can be used to build an appropriate formal model for victims' stress during natural disasters.

Computational models are models that can simulate a set of dynamic processes observed in a natural world in order to obtain knowledge of these processes and to predict the outcome of natural processes by given a specific set of input parameters (Aziz, 2010). This study aims to develop a computational model to understand the condition of victims' stress during natural disaster based on the identified psychological attributes and relationships related to victims that can be used later on to produce a virtual simulation for training or intervention systems.

1.2 Problem Statement

Disasters such as tsunami, flood, and earthquakes are some of the most natural phenomenon's that contribute to high level of mental health consequences such as posttraumatic stress disorder and a variety of other disorders and symptoms in victims as well, these disasters threaten lives thus causing a lot of stress, fear , and anxiety (Nasir et al., 2012) . These conditions especially in natural disasters can influence how victims feel about self-daily activities and well-being (Johari & Marzuki, 2013). In respect to natural disaster, Malaysia is one of the countries that are affected continuously by flooding and resulted in high percentage of victims suffering from psychological problem that resemble stress. Stress is simply a reality of nature when forces from outside world disturbing the individuals and they respond to these forces in a manner that affect them as well as their environment.

Current state of the victim's stress during natural disaster from psychological perspective must be studied to provide intelligent support that can be programmed by a computer system. However, in order to achieve this, a formal model is needed to serve as a fundamental element for building an intelligent aid system. Much research have been conducted to develop formal models in a number of psychological domains such as language, attention, and performance but there is little focus to model victims' stress during natural disasters (Soleimani & Kobti, 2012; Thilakarathne & Treur, 2013; Vancouver, Weinhardt, & Vigo, 2014). Thus, the aim of this study is to present a computational model that can be used to simulate the dynamic of victim's stress under the effect of disastrous events such as floods relating to series of cognitive factor within individuals. Moreover, a formal model is valuable to formulate ideas and identify underlying assumptions with well-defined principles for manipulations. In view of the fact that an intelligent system is a computer implemented procedures that look towards combining domain knowledge with abstract mathematics and reasoning that is translated into simulations of experiments, a formal model is thus a suitable mechanism to support for the underlying construction of an intelligent system.

1.3 Research Questions

The main research questions for this study are:

1. What are the psychological / cognitive attributes and their relationships that influence the stress level of victims during natural disaster?
2. Can a computational model be used to understand victims' stress during natural disaster?
3. How to evaluate the proposed model via mathematical and automated verification analysis?

1.4 Research Objectives

The study is undertaking to accomplish the following objectives:

1. To identify psychological / cognitive attributes and relationships related to victims' stress level during natural disaster.
2. To develop a computational model of the identified psychological attributes and its relationships to understand victims' stress during natural disaster.
3. To evaluate the proposed model by using selected cases via mathematical and automated verification analysis.

1.5 Scope of the Study

The study focused on victims' stress (adults) during natural disaster, such as flood in Malaysia, in terms of psychological effects through the development of a formal model. Theories from the cognitive science and psychology, as well as attributes and its relationships related to victims' stress during natural disaster are explained to build the proposed formal model. For this study, a formal model based on differential equations (computational model) is developed to simulate several conditions of a victim’s stress.

1.6 Significant of the Study

There is a technical solution to the attainment of complex human functioning process through the implementation of a formal model. In such, the descriptive nature of psychological theories and models of victims' stress during natural disaster can be transformed into a causal-mechanistic stage to illustrates important relationship between a set of observed phenomena that is valuable to serve as a foundation to designing an intelligent software agent than can predict and support victims with predisposed stressors .

In the same vein, by implementing this model with any digital artifacts (virtual agents and robots), could serve the officers and volunteers of flood evacuation centers as a simulation training environmental tool to understand internal and external processes of victims’ stress. Furthermore, this formal model can facilitate psychologists through many benefits such as acquiring more insight into victims' stress during natural disaster by simulating multiple conditions on digital environments.

1.7 Outlines of the Study

This study is organized in five chapters. An outline of the essential contents of the following chapters is expressed as follow:

- **Chapter 2:** reviews related studies on victims' stress and computational model aspects.
- **Chapter 3:** discusses the research methodology that was used to construct a formal model.
- **Chapter 4:** presents the formal model.
- **Chapter 5:** concludes the findings of the study.

1.8 Summary

This chapter presents the background of the study. It introduces the research problem, research question, and objectives. In addition the purpose of the study is highlighted through the development a formal model (computational model) that can simulate victims' stress during natural disaster.

CHAPTER TWO
LITERATURE REVIEW

This chapter discuss briefly on disasters, with specific emphasis on the effects of disaster as related to psychological problems. Then, the chapter presents reviews about stress, definition of stress, stressor, and level of stress, theories and models of stress and finally the explanation of computational modeling in psychological and cognitive domain with related examples.

2.1 Disasters

Catastrophes or as well-known as disasters are natural phenomenon that have been extensively illustrated from additional categories of distressing episode by applying the definition of "massive collective stress" or" violent encounters with nature, humankind or technological" (Kinston & Rosser, 1974; Norris, 1992). The dimension and subsequent possibility of disasters reports through broadcasts by public and mass media are frequent with regards to regular occurrences; with some approximate placing their rate at an average of 1 per day somewhere across any region in the world (Norris, Friedman, Watson, et al., 2002).

Literally, there are several categories of disasters such as, earthquake, flood, tsunami, hurricane, and nuclear catastrophe, bombing attack, mass shooting, transportation accidents, and many more. Through this unfortunate event, individuals' mental health can be affected through several reasons, for example; 1) The capacity of individual acceptance of adaption will draw to several mental consequences that can lead to post-traumatic stress, 2) Technically, individual's ability to adapt is a matter of predetermined time, and 3)The influence may be continuous, often for a very long time of post-event reflecting extra load or stress to the individual which is the basis of emotional and physical disturbance.

Based on the evidence by (Eshghi & Larson, 2008; Granot, 1998), there has been a stable increase in the magnitude of disasters. First, the quantity of disasters related to natural hazards such as storms, earthquakes, and flood has increased significantly since the second half of the last century. Second, the societies are more frequently confronted with technological disasters since the beginning of 1970s and, third, disasters related to health (e.g. infectious diseases and epidemics) have also increased in recent years. In addition to this increasing trends, great deals of disasters being faced today have much impact on nature compared to those in the earlier decades (for example – populated area vs. non populated area).

There are numbers of research and studies on disasters have examined the possible impacts of natural hazards. These scenarios can be divided into two tracks. Firstly, the studies focused on economic analyses and tried to approximate or predict the potential possible death toll, property damage, and cost implication of disasters through statistical multifaceted approach and methodology by pre-stipulating modifications and circulations of variables to the main point of contribution (Ding, 2007; Garrett, 2005; Karesh & Cook, 2005; Mileti, 1999). Secondly, it evaluates the possibility and prospect of endurance of psychological outcomes after disasters, specifically post-traumatic stress disorder (PTSD), through occurrence follow-up case analysis. Hence, from aftermath of disaster, it have been reviewed and investigated to estimate victims post-impact reactions, and formerly rated to search for numerous years after disaster to attempt and comprehend the factors relating to reduced and enlarged hazard for PTSD which might perfectly help individual recovered from their disaster distress (Clarke, 2003; Johnson, 1987; Norris, Friedman, & Watson, 2002; Norris, Friedman, Watson, et al., 2002; Quarantelli & Dynes, 1977; Udwin, Boyle, Yule, Bolton, & O'Ryan, 2000).

Thus, it is obvious when people are unprotected to any kind of disasters; the post-events demonstration had made different indications or symptoms apparent throughout or even afterward of any disaster. A number of people who are predisposed are more often vulnerable than others and the significant effects are predicated on individual characteristics. For example, if the individuals are used to the environmental trauma or disaster's nature itself, the impact of such event may less significant (Koopman, Classen, Cardeña, & Spiegel, 1995).

2.2 Type of Disasters

Definitions of disasters have been illustrated by Turner and Pedgeon (1997), the World Health organization (2003), Richardson (1994). Also, its various kinds of disasters have been reviewed and were reported to include; natural disaster, hybrid disaster, and man-made disaster that wrapped all categorizes of disastrous events. Long-term disasters tend to point out to national and international conflicts.

2.2.1 Man-made Disasters

Man-made disasters are those disastrous events that are consequence of human decisions. It can be sudden or long term disasters and it is highly related to the socio-technical disasters. Richardson (1994) showed that socio-technical disasters occur in at least four types of organizational situations. These are technological disasters (plant and factory failures), production failures, stadia or other public place failures, and transport failures (Shaluf, 2006).

-Technological Disasters has been defined by the International Labor Organization (1988) as an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of industrial activity, leading to serious danger that is immediate or delayed, inside or outside the establishment, and to the environment, and involving one or more dangerous substances.

-Transportation Disasters is seen as a major rail/highway accident that can produce large number of hazards material, casualties, and major disruption of very important routes. Also, air crash can happen anywhere, both outside or around the airport. Any accident that causes plentiful injuries could mediate local emergency and engross medical resources.

-Public places failure and Stadia are one of the man-made disasters. The public places failure embraces high-rise buildings, the collapse of stadia, and the urban fires. Urban fires happen in structures such as condominiums, schools, high-rise apartment buildings, etc.

- Production Failures such as computer system breakdowns and production and distribution of imperfect products.

2.2.2 Hybrid Disasters

The second type of disasters is hybrid disasters which refer to a compound of natural forces and human decisions. According to (Shaluf, 2007) examples of this kind of disaster can be summarized as follows:

- The broad clearing of jungles causing soil erosion and subsequently heavy rain causing landslides rain causing landslides.
- The location of residential areas, factories, etc., at the foot of an active volcano, or in an avalanche area, and floodplain disasters.

2.2.3 Natural Disasters

Natural disasters are catastrophic events consequential from natural hazard. Natural hazards resulted from external (topographical such as landslide and avalanches), internal (beneath the earth's surface such as earthquakes, tsunamis, and volcanic), weather-related (meteorological/hydrological such as tornados, floods, drought, and heat wave), and biological phenomena (epidemics and infections). Natural disasters are beyond human control and it has a common denominator, which is the severity of their impact on property, people, and environment.

With regards to Malaysia, though the country is geographically located outside the *Pacific Rim of Fire* and is somewhat free from destruction and severe ravages caused by natural disasters such as volcanic eruptions, typhoons, and earthquake, nevertheless the country is subjected to landslides, monsoon floods, and severe haze episodes. Similar to other natural disaster, floods can produce too many fatalities from drowning and damages to properties, for example, plantations, house, livestock, and others. Flood catastrophe has created pain, suffering, and misery among victims. In relation to this, flooding in Malaysia already made unusual situational impact on human psychological imbalance that includes stress and depression. The quality of human life is directly changed and evokes trauma yet disturbances as a result from this event. In addition, the epidemic outbreak after flooding disasters had gained much impact victims and widespread of diseases.

It is vital to know that people living in certain area that are predominantly scale of floods disaster need be reminded and constantly alerted to protect their live from it. Prevention is highly recommended for people to minimize the effect of floods disaster. For example, victims are regularly plagued by flooding that has happened before and this gave rise to stress and anxiety among flood victims. In general, flood can be classified into three categories; namely monsoon flood, tropical flood, and flash flood. In Malaysia, the most experienced flood is the monsoon flood caused by the impact of continent location and sea water level (Liu et al., 2005).

Areas that are exposed to serious flooding span across 29,800 kilometers, which make up about 9 percent of the total land mass in Malaysia. They are affected by monsoon flood disaster (Johor, Kelantan, Terengganu, Pahang, Sabah and Sarawak). On the other hand, states such as Pulau Pinang, Melaka, Selangor, Negeri Sembilan, and Wilayah Persekutuan Kuala Lumpur only experience flash floods. Meanwhile, in 2010, these flash floods translated to nightmare when it turned into a natural disaster and affected areas that had never suffered flooding before. Table 2.1 illustrates the total number of flood victims (Johari & Marzuki, 2013).

Table 2.1: The Total Number of Flood Victims in Malaysia (year 2013).

State	Number of relief centers	Number of families	Number of victims
Perlis	57	2,921	15,261
Kedah	202	15,257	64,924
Kelantan	45	1,622	5,311
Terengganu	84	1,499	6,061
Johor	376	30,276	116,660
Melaka	32	2,325	9,089
Negeri Sembilan	27	715	3,083
Pahang	45	961	4,650
Sabah	20	903	3,389
Sarawak	18	615	2,949
Total	906	57,094	231,377

2.3 Psychological Effects of Disasters

There a number of theories could be used to explain the psychological effects of disasters. For example, the Conservation of Resource Theory (COR), victims try to protect resources such as energy (financial investments, time), social roles (employment, marriage, etc.), objects (housing, possessions, etc.) and personal characteristics (such as self-confidence). The threat or real loss of these kinds of resources as caused by disasters leads to psychological distress (O'Neill, Evans, Bussman, & Strandberg, 1999). Normally observed situations such as emotional disorders rarely come to the considerations of psychiatrists but may negatively affects work performance and social relationships. Regularly detected symptoms are fatigue, cognitive experiences such as impaired concentration, confusion, attention deficit disorder (Lutgendorf et al., 1995).

Furthermore, behaviour effects such as substance abuse, sleep, and appetite changes as well as emotional signs such as depression, anxiety, and grief, were also reported (Lindell &Prater, 2003). In several reported cases, the suicidal rate among earthquake victims (people who had experienced property loss or lost family members residing with them or were injured) were 1.46 times more prone than non-victims to commit suicide (Y.-J. Chou et al., 2003). All these impacts can be easy-going and fleeting or can lead to Post Traumatic Stress Disorder (PTSD).

According to (Sadeghi & Ahmadi, 2008), the mental states of victims can be classify into three stages, firstly, immediate reaction including distress symptoms accompanying adaptive stress, secondly, post-immediate phase which covered symptoms of maladaptive stress (agitation, confusion, and in some circumstances neurotic or psychotic reactions), thirdly, the long term sequel which involve a return to standard health or the onset of PTSD, that can occasionally yield a chronic phase that will involve personality changes. Moreover, possible psychological effects normally start immediately rather than long period after actual disaster such as the 2004 water scarcity which shows how fear and anxiety about an event influence the public's response.

In the months after the 9/11 terrorist attacks, anthrax cases produced not only a lot of fear about bioterrorism but also collective anxiety nationwide. Likewise between October 2001 and June 2002, a mysterious skin rash disturbing too many students in the primary school were reported in mostly 27 separate locations in the U.S. and some parts of Canada. In the wake of extensive bioterrorism fears, student showed high attention to their skin after hearing media reports of coetaneous anthrax. The Centers for Disease Control and Prevention (CDC) concluded that with 53 million young people attending 117,000 schools each school day in the United States, rashes from wide range of causes simply will exist.

On the basis of human mental functioning, reactions to the threat of disasters may be classified into four categories according to (Ursano, Grieger, & McCarroll, 1996), interpersonal (e.g., externalization of vulnerability, distrust, impaired work or school performance, and social withdrawal), physical (such as fatigue, exhaustion, vulnerability to illness, reduced immune response, and startled response), emotional (e.g., feelings of shock and helplessness, sadness, loss of pleasure), cognitive (such as disbelief, impaired concentration and decision-making ability, and decreased self-efficacy) effects. If they happen, these effects weaken people's response abilities during the course of a disaster.

To sum it up, whatever kind of disasters, be it human-made or natural disasters will attack a wide area of civilization population and can be treated as external forces that affects people in that area. According to (Ding, 2007), people who are available in that field of disaster may be influenced to various degrees of psychological damage; normal ,low, moderate, and high.

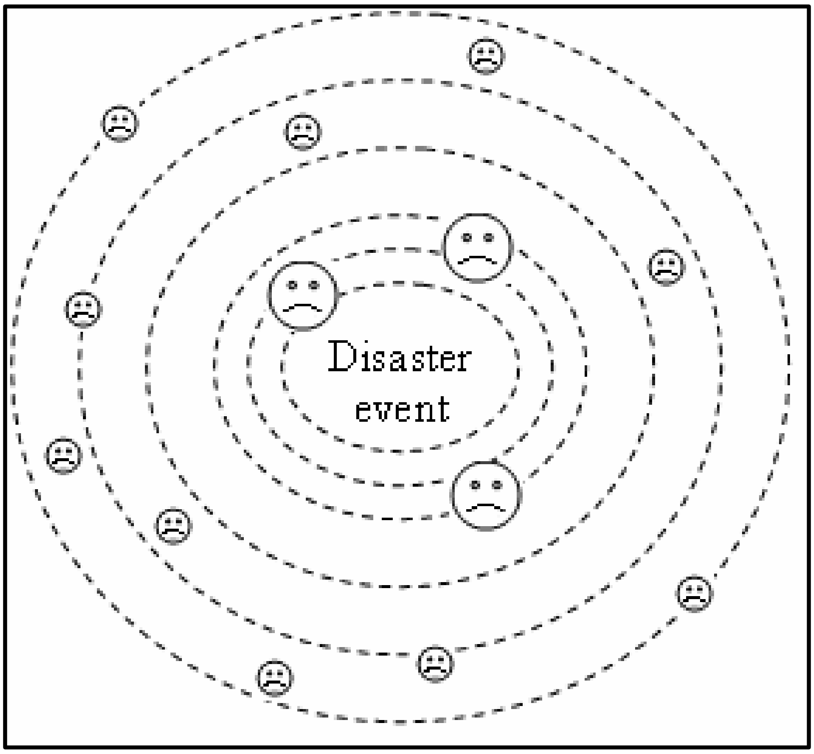

Figure 2.1: Disaster Field

Also, when individual perceives threat, the brain regions such as amygdala, cortex, and hippocampus, interpret that threat in terms of biological and cognitive interpretation. Later limbic system processes this information that manipulates emotional behavioral responses such as; resemble anxiety, anger, sadness, or even fear. Previous post-analysis conducted by researchers have proved that affected people may exhibit decreased self-efficacy, startled response, reduced work performance (emotional exhaustion and burnout), or reduced working hours (Ding, 2007). Figure 2.2 illustrates how an individual mentally will perceive risks and react to it.

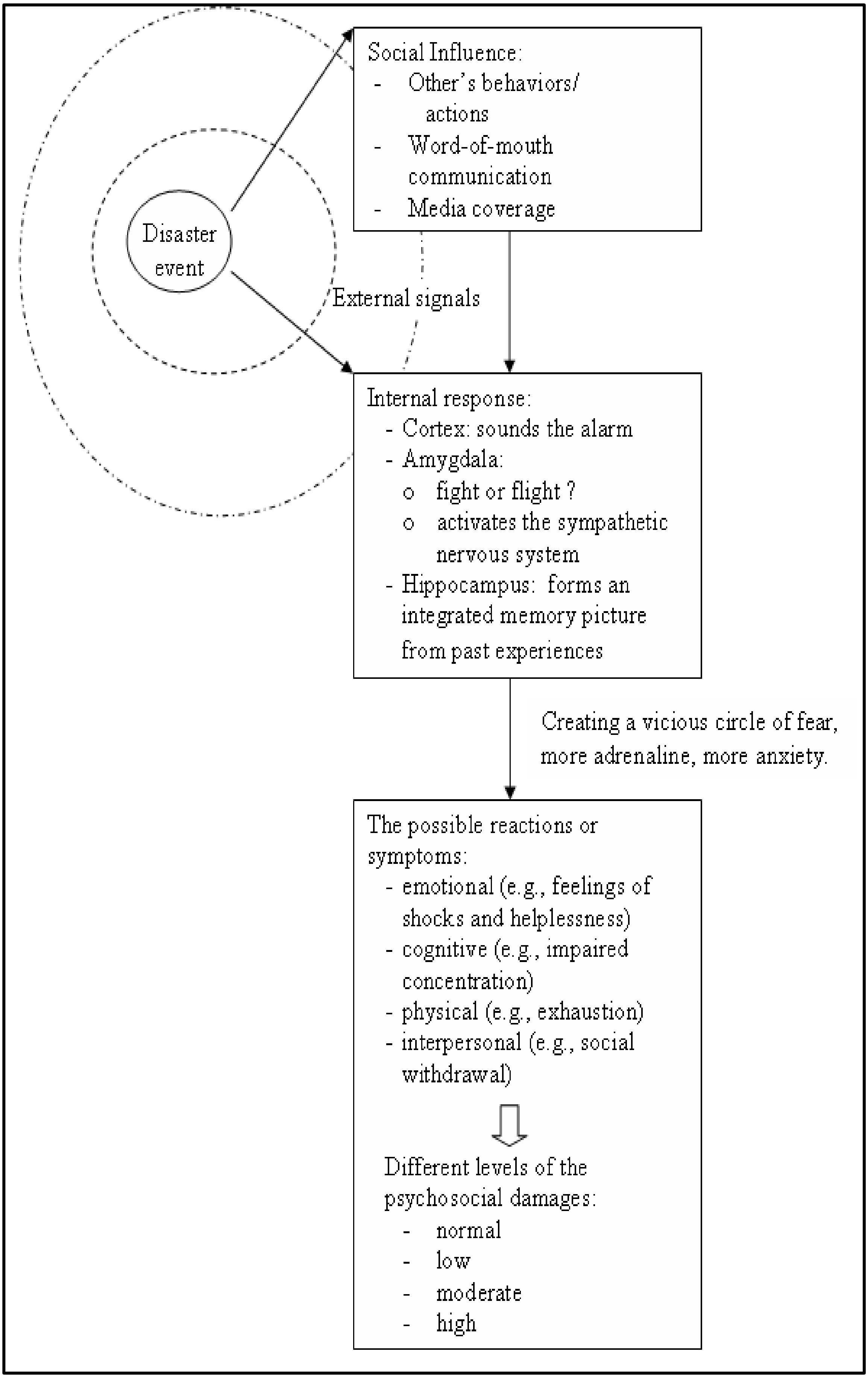

Figure 2.2: Individual Mental-level Risk Perception and Reaction (Ding, 2007)

2.4Stress

2.4.1Definition of Stress

In behavioral and health sciences, the term stress has enjoyed increasing popularity for the last five decades. Stress has become a growing concern in modern society. Many authors have defined stress in various ways and discussed that stress has vital role of human costs in term of physical and mental illness.

- Stress is a mental or physical phenomenon created through one's cognitive appraisal of the stimulation and is a result of one's interactions with environment (Lazarus & Folkman, 1984).
- Stress is a state of physical or mental tension that causes emotional distress or even feeling of pins to an individual by Chang's Dictionary of Psychological Terms (Kai-Wen, 2010).
- Stress is occurring when the perceived pressure exceeds your perceived to cope and that is the most important definition of stress(Palmer, Cooper, & Thomas, 2004).

2.4.2 Types of Stress

The positivity of stress has exceeded into the type of stress itself. Indirectly, the positivity of stress has sustained the individuals to stay active and advance in life. This category of stress has identified as "eustress". The negativity of stress is precisely effect of the mental causes that became more ill-tempered, spiritless, and immerses us into the darkness. All of the negativity impact of stress generally called as distress. When individual faced stressful situation, the body respond specifically in a manner to prepare for threaten action.

Stress is a very common psychological stimulus to human lives. That drives individuals to be more dependent and keep going to the positive way to achieve the aim of life (Stephen et al., 2004; HSE, 2001). By classifying stress, it could result to physical, mental and environment. The pointer of physical stress is such as over workload, restless, lack of nutrition and poor diet. Other pre-outlook is a person's mental matter and mind-set, for examples is hope, faith, regret, and fear within face of reality. Additional outlook is environment stress, define that a consequence of appearance by social and universal interface, such as husband, father, wife and mother. Gadget stress issues could be the other indicator for distress measurement, such as imprisonments by modern gadgets, sophisticated fancy cars, computers, and cell phones.

2.4.3 Stressor

Stressors are the conditions, process measurement of stress that arouse tension or stress. Stressors can be solitary occasions, for examples are critical life events or traumatic experiences and chronic difficulties that persevere over a longer period of time. It can be categorize into many classes such as traumatic events, physical stressors, role-stressors, work-related of job stressors, time-related stressors, career-related stressors, and social stressors.

- **Physical stressors** is state to malignance of bodily working as well as blast, dirt, temperature, ambiances, chemical, or toxic ingredients. Those are also containing to unfortunate ergonomic environments at the work place and misfortunes; and physical stressors have psychological effects.

- **Task-related job stressors:** by performing whereas doing a job task and containing with high time heaviness and over workload, high difficulty at work place, repetitive work task and disturbances (e.g., caused by an unexpected computer shutdown).

- **Social stressors:** precisely in social interface of deprived situation by having direct communication with supervisors, co-workers, and others. Those stressors are embracing personal contravention at work place, (sexual) harassment and bullying.

- **Career-related stressors:** consists of job uncertainty and impoverished career chances.

2.4.4 Levels of Stress

According to (Robbins, 2010), stress level can be measured by physiological, psychological and behavioral indicators. Similarly, Walt (1987) likewise debated that stress level can be revealed through physical, emotional, thinking and behavioral distress indication.

- **Physical:** the characteristic of physical level of stress can be marked by aridness of mouth or throat, common lethargy or immensity, slow recovery from stressful event, trembling, prodding of health from tension, headache, chest pain, neck pain, upset stomach, loss of appetite, frequent need to urine and increase appetite.

- **Emotional:** the typical of this level stress on emotional such as dampen sense, emotional instability, the tendency to escape, to hurt someone, unhappiness, fear of future and upcoming event, fear of deteriorating, insomnia or sleeplessness, more impatience, hopelessness, and many more.

- **Thinking**: the thinking description is such as, uncertain, ambiguous, senile, mentally blocked, bizarre, lost focus and concentrate, disconnect thought, having terrible nightmare, inward obsession, disorderly and incoherent.

- **Behavioral:** The behavior has effected of the level of stress such as bad temper, uncontrollable, loud-mouth, garrulous, easily provoked, stumbling on speech, grinding teeth, restless, anxious, interpersonal conflict, introvert, maudlin, overemotional, and shrieking out for something.

2.5 Theories and Models of Stress

The researchers have shown the precise theories and models of stress in different domains, namely;1) Hobfoll's Conservation of Resources Theory (1989),2) Diathesis-Stress models (Zubin & Spring, 1977),3) Hans Selye's General Adaption Syndrome model(1950),4) Transitional Model of Stress and Coping (Lazarus & Folkman, 1984), 5 and 5) Cognitive Activation Theory of Stress(Ursin & Eriksen, 2004), for every of this theories and models have been providing the diverse of thoughts and concept about factors that might be obliged as mediators or moderators in particular variables in pressure and stress of psychology relationship and correlation. Therefore, why and how mental and health causes might be altered of stress acquaintance and period of time. Every single theory has defined the result of stress in different manner and also placing of changing the prominence on psychological, social, ecological, and biological dynamics and practices.

2.5.1 Conservation of Resources (COR)

The theory of Hobfoll's Conservation of Resources (COR) emphasizes on social-ecological concepts about stress practices and mental health. According to (Hobfoll, 2001) socio-cultural issues is related to certain criteria such as gender, race, and poverty. The COR theory is esteem of external and objective experiences (rather than internal, cognitive, and psychological experiences) as the primary influences on stress, mental health, and coping. This theory explains that resources loss is central to the experience of psychological distress and stress is based on loss of or threat to an individual's resources. At this point, resources are "those objects, conditions, personal characteristics, or energies that are valued by the individual or that serve as a means for attainment of goals and further resources (Hobfoll, 1988). Personal characteristics (e.g., self-esteem, optimism, sense of mastery), objects (e.g., car, clothing, and house), energies (such as time, money, knowledge) and conditions (e.g., family stability, companionship, and employment) are all examples of resources.

According to the theory, people are driven to obtain, preserve and regain resources, and that endeavors to improve misplaced of capitals or resources and preserve vulnerable resources to oblige investment and asset of other resources. Briefly, recovery from stress (threat or loss) is itself of nerve-wracking and from that perspective; Hobfoll has highlighted the effects of the inequitable distribution of resources.

Precisely in the past, the individuals who have fewer resources are smaller size of being prepared of recovery. Because of some individuals have not any resources to replacement, efforts to recover from losses is become indication to advance the reduction of resources. For an instance, the capability to recover from stress has inclined through the interface among total of loss or threat that continued and the total of previous resources and subsequent of stress. COR is continuously a claim that resource which might be loss would have more influential on mental health and well-being. As compared with resource gain, this is particularly the case when losses occur in the context of low resources (Wells, Hobfoll, & Lavin, 1999) .

2.5.2 Diathesis-Stress Models

The diathesis-stress model was first introduced by (Zubin & Spring, 1977) for schizophrenia and mental stress. However, comparably of COR, the model of diathesis-stress has represented stress as major of external condition of experience. Dissimilarity of COR is the diathesis-stress models tend to control the individual based on them biological or cognitive function as a main key in connection among stress and mental health. In addition, while COR theory has more focusing on recent practices, socio ecology, and protective factors (i.e., resources), the model of diathesis-stress have a tendency to be more developmentally, individually and interpersonally focused, concentrating on pre-natal and premature childhood risk elements, such as the effects of primary mistreatment or genetics.

The diathesis-stress models recommend that all people encounter threat for developing any specified mental health problem when faced by stress (which is frequently understood to affect physiology and brain functioning). In the same vein with COR, the diathesis-stress models proposed that the tendency for emerging problems or stress are various between and within individuals and depends on the interaction between the individuals and her or his environment. Regarding to diathesis stress models, the most important components consist of the magnitude of stress and the grouping of individual’s biological and ecological situations prior to stress. These circumstances or diathesis comprise social experiences, aspects of an individual’s development history, environment, self (such as personality, intelligence, appraisals), genetic features, inherited traits, neurological, neuro-chemical, and bio-physiological functioning (including alterations).

Monroe & Simons (1991) describes diatheses and stressors may intermingle in at least three methods. Firstly, the huge scale of diathesis influences whether it is given stressor indications to an evident of mental health problem. In particular, for those with higher diathesis (i.e., more risk), a stressor that is objectively less severe may consequence in a mental health problem and for those with lower diathesis (i.e., less risk) a more major stressor would be essential. Secondly, when a stressor has never giving any result on mental health problem, the stress might be conferred as supplementary hazard for the individual by levitation his/her diatheses. For example, exposure to stressors may gather over time, weakening the individual's capability to withstand a later stressor.

The diathesis-stress models have therefore emphasized the roles of recurrent and chronic of stress, such as that occurring as an outcome of repetitive childhood exploitation, urban poverty, discrimination stress, and neighboring fierceness. Finally, diathesis might be in some way increase risk of exposure to extremely stressful experiences. This will lead to the classical psychological conditioning such as when an individual has been abused in childhood; she/he might be in the high level of risk for adulthood of discrimination.

2.5.3 Transactional Model of Stress and Coping

The transactional model of stress and coping (Lazarus & Folkman, 1984) has been mostly investigated, and at present, its theoretical underpinnings are extensively accepted by practitioners and researchers (Cooper, Dewe, & O'Driscoll, 2001; Yu, Chiu, Lin, Wang, & Chen, 2007). The fundamental concept of this model is that a potentially stressful event will cause the primary appraisal process in which an individual estimates the degree of threat in relation to his or her wellbeing. When a situation is perceived as life threatening, harm-loss, or challenge; the secondary appraisal process provides a global assessment of the individual's coping resources and ability to manage the demands of event.

Coping responses are begun after the cognitive appraisals and the eventual psycho-physiological occurrence (stress outcomes) of this potentially stressful event depends on the effectiveness of one's cognitive appraisals and coping processes. The stress results will then feedback to previous stages of the cognitive appraisal for further actions if required. It is worth mentioning that the sequence of manipulation processes between primary and secondary appraisal does not always present itself as one being more important than the other (i.e. primary vs. secondary), or that one always before other.

The relationship between two appraisal process is extremely dynamic but as critical processes, Lazarus and Folkman conceptualized a linear progression flowing from primary to secondary appraisals to coping process and ultimately, to stress consequences as a reflection of the essential pathways within the interplay of the dynamic process. Therefore, the key concept of Lazarus and Folkmans's transactional model is that primary appraisal, secondary appraisal and coping strategies mediate the relationship between stimuli and the individual's stress consequences.

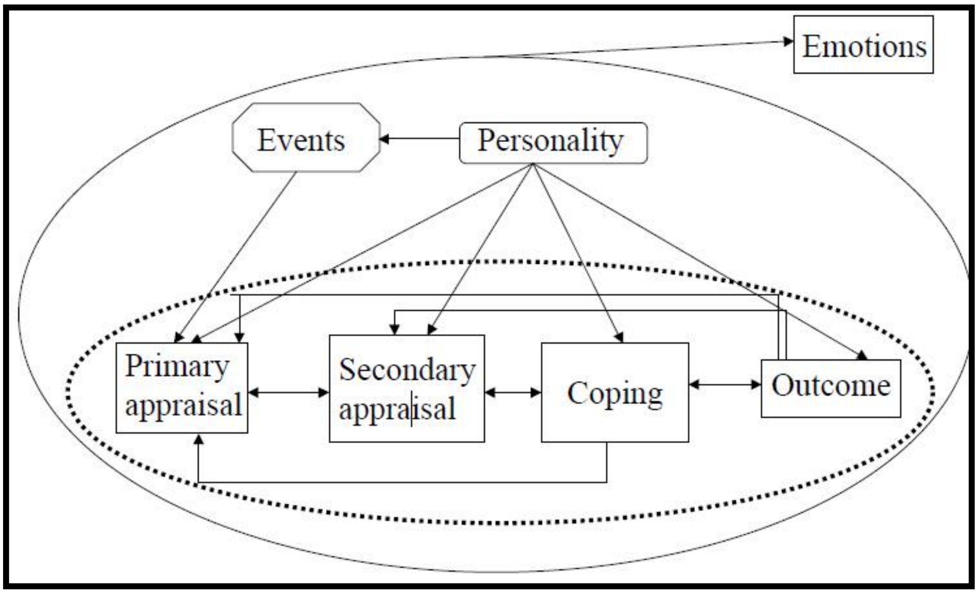

Figure 2.1: Transactional Model of Stress (Lazarus & Folkman, 1984).

2.5.4 General Adaption Syndrome Model (GAS)

GAS model has been introduced by Hans Selye (1950), which is used to illustrate the body's short-term and long-term reaction to stress. The underpinning concept of FAS is the fight or flight is a sequence of reactions to stress. GAS contains two major regulatory systems of the body, autonomic nervous system (sympathetic) and endocrine (hypothalamic, pituitary, adrenal axis). This model has three stages; 1) alarm, 2) resistance, and 3) exhaustion. These stages are depicted in Figure 2.2.

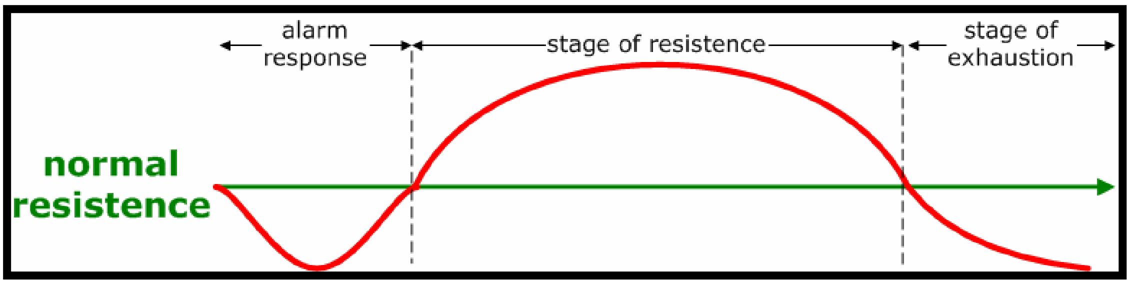

Figure 2.2: General Adaption Syndrome Model

- **Alarm**

  The first stage of general adaption syndrome is the instance reaction to stressor. In the initial step of stress, individuals expose to fight and flight response; and sympathetic nervous system is activated, which causes ready for physical activities. To meet the threat or danger hormones such as cortisol, the adrenalin will be released. However, this initial response will reduce the effectiveness of our immune system, and making individuals more susceptible to illness during this phase.

- **Resistance**

  If the reaction persists and is not strong enough to cause life threatening situation, then the physiological reaction enters the phase of resistance, where the body attempts to adapt to the perceived stimuli. In the same time, physiological arousal is monotonically reduced but still stays higher than standard. This can be accomplished through the hormones released by the adrenal glands. During this phase, human body may demonstrate a few signs of stressful conditions. However, if the body may not be able to cope against new stressor then body becomes vulnerable towards health problems. These health problems include high blood pressure, ulcers, and illnesses that consequence from impaired immune function.

- **Exhaustion**

  Repeated stress or severe long-term stress will cause the organism to enter exhaustion phase. The immune system and the body's energy reserves are weakened until resistance towards stressors is become very limited. If the stress persists, physiological damage and disease become ever more likely and death will be inevitable.

2.5.5 Cognitive Activation Theory of Stress

The cognitive activation theory has been developed by (Ursin & Eriksen, 2004), it offers a psycho-biological illustration for the inter-relationship between internal and external event with the respect of stress and health. Four aspects of term stress have been used such as; stress stimuli (stressors), stress experience, the non-specific general stress response, and the experience of the stress response. Stress response is described as a general alarm in homeostatic systems. This will cause a general and unspecific neuro-physiological activation from one level of arousal to a higher level of arousal. The alarm is triggered when there is a discrepancy between what should be and (set value) and what is happening in reality (actual value). Moreover, if the alarm is sustained, the response may lead to illness and disease through established pathophysiological process. The outcome of stimuli and the specific response available for coping determine the level of alarm. The concept of positive, negative, or none are explained as an elements of response outcome expectations to the available response, thus, response outcome expectancies offers formal definition of coping, hopelessness and helplessness that are easy to operationalize in man or even animals.

-Coping (positive response outcome expectancy) is the acquired expectancy that most or all responses lead to a positive result. This leads to a reduced arousal level.

-Helplessness is the acquired expectancy that there are no relationships between responses and reinforcement.

-Hopelessness (negative response outcome expectancy) is the acquired expectancy that most or all responses lead to a negative result.

The psychological stress response may lead to straining or training according to the type of the activation.

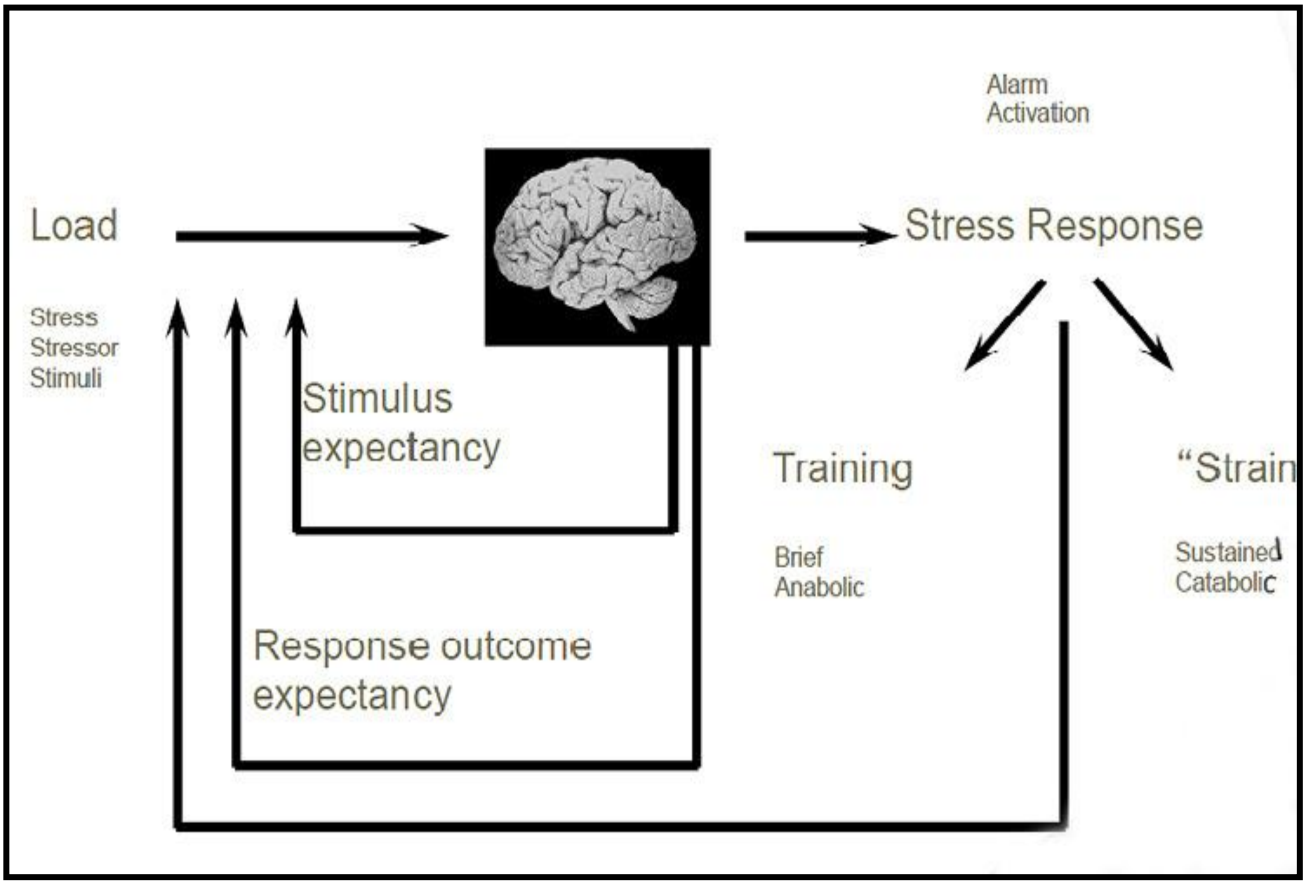

Figure 2.3: The Cognitive Activation Theory of Stress (Ursin & Eriksen, 2004).

Table 2.2 summarizes the whole of the aforementioned theories,

Table 2.2: Theories of Stress Models

Author	Year	Theories	Concepts
Hobfoll	1989	Conservation of resources	The COR theory is esteem of external and objective experiences (rather than internal, cognitive, and psychological experiences) as the primary influences on stress, mental health, and coping. According to COR theory resource loss is central to the experience of psychological distress. The definition of stress is based on loss of or threat to an individual's resources.
Zubin and Spring	1977	Diathesis –Stress Models	The model of diathesis-stress models has represented stress as major of external condition of experience. Diathesis-stress models tend to control the individual based on them biological or cognitive function as a main key in connection among stress and mental health.
Lazarus and Folkman	1984	Transactional stress Model	The core concept of this model is that a potentially stressful event will cause the primary appraisal process in which an individual estimate the degree of threat in relation to his or her wellbeing. When a situation is perceived as threatening, harm-loss, or challenge; the secondary appraisal process provides a global assessment of the individual's coping resources and ability to manage the demands of event
Ursin and Eriksen	2004	Cognitive activation theory of stress	Stress response is described as a general alarm in homeostatic system, causing general and unspecific neurophysiological activation from one level of arousal to a higher level of arousal. The alarm happens when there is a discrepancy between what should be and

			(set value) and what is happening in reality (actual value).
Hans Selye	1950	General Adaption syndrome (GAS)	GAS model has been introduced by Selye(1950),which is used to illustrate the body's short-term and long-term reaction to stress. He found the fight or flight is a sequence of reactions to stress. This model has three stages alarm, resistance, and exhaustion.

2.6 Concepts Related to Individuals' Stress during Stressful Events

2.6.1 Resilience

The concept of resilience came from the field of engineering which is related to the physical strength of material. Psychological resilience was derived from the idea of physical resilience and has been defined in a number of ways. (Sherbourne & Gaillot, 2011). In spite of its universality, there is no single approved definition for psychological resilience (Wald, Taylor, Asmundson, Jang, & Stapleton, 2006). It has many shared definition for some familiar attributes, such as strength to tolerate some type of traumatic stress or adverse circumstances. However, the most important definition of psychological resilience is the capacity to adapt successfully in the presence of risk and adversity (Jenson & Fraser, 2006). In addition to this, individuals with poor level of resilience are less able control and cope with stress (P.-C. Chou, Chao, Yang, Yeh, & Lee, 2011; Steinhardt & Dolbier, 2008). Meanwhile, those who are in good personal resilience are often capable of handling adversities and recover smoothly (Steinhardt & Dolbier, 2008).

Moreover (Rutter, 2012) refers to resilience as a conclusion based on evidence that some people have a better result or outcome than others who have experienced a same level of stressful events. The undesirable experience may have either strengthening or sensitizing effect related to later stress or any traumatic events. Consequently, in the report conducted by S. Maddi (2013), the researchers have proved that hardiness (existential courage within an individual) enhances the pathway to promote resilience within an individual. This explains resilience as a phenomenon of maintaining the performance and health of individuals in spite of the number of stressful circumstances.

Sherbourne & Gaillot (2011) conducted a systematic review of the scientific literature on psychological resilience to identify evidence-informed factors that promote psychological resilience among U.S military personnel. It was found that twenty factors are associated with resilience. Those factors were used to categorize resilience into four main pillars, namely: 1) *Individual-Level Factors* (positive coping, positive effect, positive thinking, realism, behavioral control, physical fitness, altruism), 2) *Family-Level Factors* (emotional ties, communication, support, closeness, nurturing, adaptability) 3) *Unit-Level Factors* (positive command climate, teamwork, cohesion) 4) *Community-Level Factors* (belongingness, cohesion, connectedness, collective efficacy). Resilience does not get rid of stress or remove life's difficulties but it gives individual the strength to tackle problems and hold on, overcome trouble and move on with their lives.

2.6.2 Coping Strategies

Coping has been defined as thoughts and behaviors that individuals use to manage the external and internal demands of situations which are appraised as stressful (Folkman & Moskowitz, 2004). Coping contains a broad range of behaviors and cognitive responses that may be used to evaluate stress. These responses are frequently referred to as coping strategies, and may be either maladaptive or adaptive (helping a person to manage stress or eliminate stressor). Many coping strategies have been illustrated across studies whereas different situations will in some circumstances require different types of coping, and a strategy that is valuable in one situation may not be successful in a different situation(Skinner, Edge, Altman, & Sherwood, 2003).

Coping strategies have been mostly divided into a problem-focused or emotional -focused. Task-oriented coping or problem focused encompasses acting to change a situation whereas it no longer causes a stress (interpersonal and rational efforts to change the situation and to get the problem solved). In contrast to this, emotional-focused is associated with necessities to regulate the emotional consequences of potentially stressful event (thinking rather than behaving to change the individual-environment relationship) (Baker & Berenbaum, 2007). Emotional-focused normally include escape, distancing, avoidance, and looking for social comforts. Numerous findings revealed that the kind of coping strategies is chosen via depending on what was the primary appraisal and what the coping options were (secondary appraisal) (Lazarus, 1991; Ntoumanis, Edmunds, & Duda, 2009). That’s mean, when individuals feel that they are able to change the situation to something better (high perception of acceptance), problem-focused coping will be selected. In relation to this, when a condition is not amenable to change then emotion-focused coping is taken (high perception of holdback).

In addition, problem focused coping strategies give individual high perception to control over their problem, while emotion focused-coping strategies may lead to a reduction of control over the perceived event. All these strategies can be proven to be useful, but many individuals feel that problem-focused coping represent a more effective means of coping in adversities (Uehara, Sakado, Sakado, Sato, & Someya, 1999). To this end, personal resources (such as self-esteem, energy, and capability), when available, help individual to cope, and are normally considered to buffer the effect of a stressor on psychological consequences.

2.6.3 Social support

Social support is something that most individuals perceive it as a useful element in order to handle stressful events or any negative events especially when people are trying to cope with unpleasant circumstances such as stress which initiates as a consequence of disasters. Our physical and mental health can be affected by quantity of social support that we receive during negative events. Social support is getting from our relationship with family, friends, and even from acquaintances, these kinds of relationships have positive influences to individuals' health through various types of social support that they offer, containing emotional support, instrumental support, informational support, and companionship support. As a result, the existing social support is playing an important role to be predicted ingredient which helps individuals to cope with stress (Lakey & Orehek, 2011). It has shown in a number of circumstances that the types of support either be useful to one person or a negative when he/she facing a stressful circumstances (Brashers, Neidig, & Goldsmith, 2004; Tolkacheva, Van Groenou, De Boer, & Van Tilburg, 2011). Depending upon the situation, support receivers may interpret some kind of support negatively, and this often decrease the positive effects of the supportive exertions (La Gaipa, 1990). Moreover, this condition may eventually escalate the negative impact of stress towards support recipients. For example, receiving informational support from unwanted and non-credible people during times of stress can also be seen as inappropriate. Thus, based on what discussed above, social support is taking a part in dealing with stressful event to encourage people in term of increasing their ability to cope.

2.6.4 Hardiness

The existential courage (hardiness) within an individual to deal with a stressful event is another prevalence factor for a person with stress. The concept of personality hardiness is firstly coined by Kobasa (1979). In particular, it is reported in some cases as personality attitudes and strategies which often provide facilitates in order to turn stressful circumstances from likely disasters to growth opportunities (Maddi, 2006; S. R. Maddi, 2013) (Kobasa &Maddi, 1984). In specific details, there are three ingredients of hardiness which are playing an essential role in order to determine the existential courage of individuals. These ingredients are control, challenge, and commitment. Commitment refers to the belief that whatever bad things get, it is essential to remain involved with the situation rather than sink in alienation. Control refers to a condition where individuals believe that they can influence the event and turn it into growth opportunities. Challenge is being in term of how individuals are viewing the stressful event either as a challenge and believe that the life by its nature is stressful; moreover, it’s a good opportunity to turn stressful circumstances into growth opportunities by trying to accept the event and challenge it. To end of this, individuals must process all these three ingredients (control, challenge, and commitment) in order to truly express an existential courage (hardiness). In addition, some findings revealed that there is a relation between individuals' hardiness and coping strategies (Bartone, Hystad, Eid, & Brevik, 2011; Hwang, Seo, & Park, 2013; S. Maddi, 2013). In facing stressful circumstances, Individuals with high level of hardiness often choose problem-focus coping strategies while emotional-focus will be chosen with low level of hardiness. On the other hand, there is a positive relationship between hardiness and social support (Eschleman, Bowling, & Alarcon, 2010). Figure 2.2 illustrates the model of hardiness (S. Maddi, 2013).

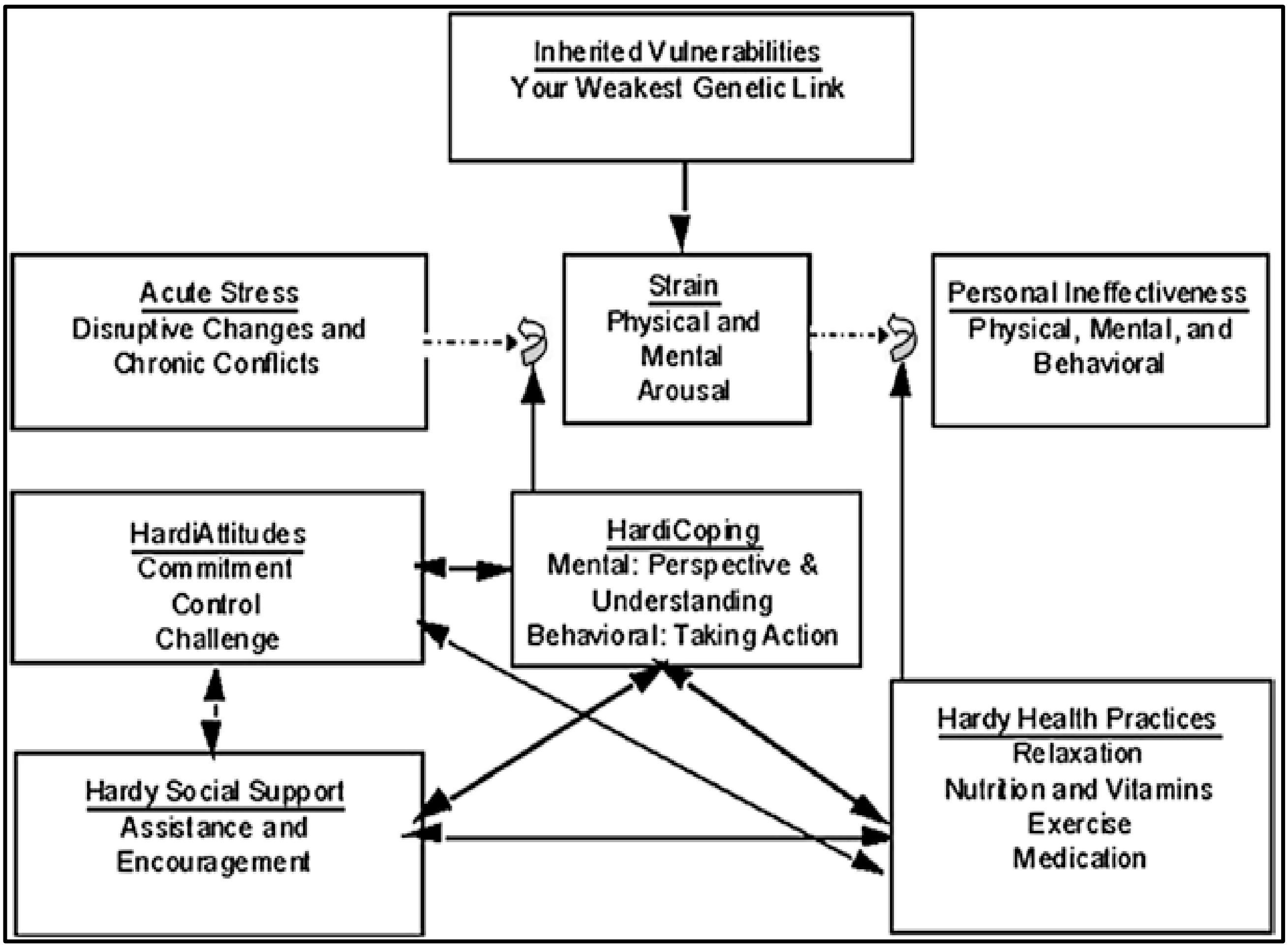

Figure 2.4: Hardiness Model for performance and Health enhancement (S. Maddi, 2013)

2.7 Computational Modeling

The concept of computational modeling refers to a process of simulating a set of processes that have been observed in the natural world in order to gain profound understanding of these processes and to predict the outcome of natural processes by given a specific set of input parameters. These models are priceless since they permit researchers to study and having revision on complete relations that may perhaps not be arranged out by virtuously experimental approaches, and to create approximations that cannot be made without difficulty by extrapolating from the existing data (Ellner & Guckenheimer, 2011).

Frequently, computational model is providing a means of undisruptive exploration in multifaceted, critical, costing, rare situation or time-consuming. A constructed computational model is accomplished of simulating certain key behaviors in the particular area of interest and concern. For instance, in a neuroscience field, theoretical neuroscientists apply computational modeling to help in understanding and explain the mechanisms of cognition. This means developing clear mathematical models of the processes which go on in the brain when we act, think, perceive, learn or remember certain tasks. In spite of the evolution of software and influential brain imaging machines that permit scientists to investigate into broader detailed of our brain activities, these technologies still unable to describe the detailed interaction between all of those activities involved. As a result, using of computational models has seemed as an instrument for external and internal investigation of cognition within brain activities.

2.7.1 Theoretical and Practical of Computational Models

Despite computational models are used for a lot of possible reasons, it cancan be categorized into two main objectives; practical applications and theoretical understanding. From a theoretical model point of view, one can realize how the real system works. In contrast, a practical model allows the prediction of the real system by which it will take part in deciding feasible sets of action (Ellner & Guckenheimer, 2011). In an extreme example, dynamic equations are usually used for expressing the theoretical models yet they are often simple enough for scientists to comprehend the underlying process. It is ineffective to replace an observed system with a complicated model that difficult to comprehend when it has not increase our deeper understanding of the observed domain.

On the contrary, practical models are generally loss simplicity in order to deal more comprehensive and precise predictions for an observed system. Hence, practical models are frequently too complex and only dedicated for computer simulations. In this relation, it should be illustrated that practical models involve detailed numerical accuracy, whereas this is not the condition in theoretical models. For that reason, the details of the process can be neglected solely if it has less affecting in making better numerical accuracy. However, in the context of theoretical models, the details of the process can be ignored if they are conceptually inappropriate to address significant theoretical issues.

2.7.2 Computational Psychology

The study of human mind and behavior in both applied and academic point to definition of psychology(Farrell & Lewandowsky, 2010). Research in psychology is looking for explaining and understanding theoretical framework of emotion, thought, and behavior.

Generally, human psychological processes are extremely complicated to understand only based on behavior observations, particularly when the underlying grounding theory of the observed circumstances is not completely understood (Scassellati, 2002). In addition, because of the complexity of the human mind, and its impact in behavioral flexibility, it produces a restricted decision that solely computational modeling can show the process and its interactions. Moreover computational modeling can be more valuable in term of intensity of process details and granularity of input-output interactions, which are fundamentally useful to illustrate the level of cognitive functions.

In recent years, computational models are often used as tools for understanding human cognitive functions and behaviors (Breazeal, Buchsbaum, Gray, Gatenby, & Blumberg, 2005;Both, Hoogendoorn, Klein, & Treur, 2008; Ting, Zhou, & Hu, 2010;Bosse, Pontier, & Treur, 2010). The models have been used to investigate the fundamental nature of various cognitive functionalities and psychology through the ongoing detailed comprehension by assigning identical computational models of representations and mechanisms. Moreover, this computational way that have been used to model cognitive functionalities of human is called cognitive modeling. According to (Detje, Dörner, &Schaub, 2003) cognitive modeling is "a method to study the human mind.

Cognitive Modelers try to explain the structure and the processes of the human mind by building them. A model of human cognition should mirror human mental activities, human errors, slips and mistakes. Cognitive modelers try to understand how the human memory works, how the human memory is structured to reflect reality, how the human memory is used for the organization of behavior. The scope of cognitive modeling is widened beyond cognition to more general and more complicated forms of psychological processes which include social, emotional and motivational factors".

It has demonstrated that computational models have succeeded to simulate related behaviors in specific domains of interests by assigning the corresponding computational processes onto cognitive functions to produce executable computational models by which the detailed simulations are performed. Results from the simulations are used to justify that the models offer good explanations of the cognitive mechanisms pertinent to the corresponding domains of interest.

2.7.3 Computational Models Related to Psychological and Cognition Models

A formal model of mood dynamics has been developed, (Both, Hoogendoorn, Klein, & Treur, 2008), to simulate the dynamics in the mood of persons, and in more especially, whether they develop longer periods a undesired moods, as in depressions. The main concepts and relations involved in this model are extracted from psychological theories about unipolar depressions and represented in a formal model of the aspect of mood and depression (as has illustrated in Figure 2.4). It supposed that each situation has a value of emotion, which represents the extent to which a situation is experienced as something positive.

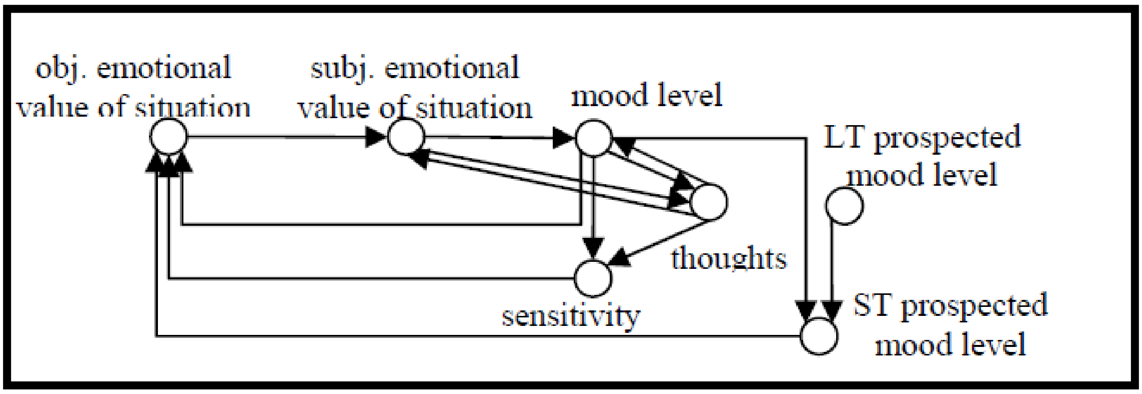

Figure 2.4: Model of Mood Dynamics.

Table 2.3 introduces related computational models in cognitive and psychology with the respect on its underlying techniques.

Table 2.3: Computational Models in Cognitive and Psychology

Author	Year	Title	Technique
Lik Mui et. al.	2002	A Computational Model of Trust and Reputation	First Order logic
Gebhard	2005	ALMA – A Layered Model of Affect	Rule Base
Paul Cisek	2006	Integrated Neural Processes for Defining Potential Actions and Deciding between Them: A Computational Model	Differential Equation
Amy (Wenxuan) Ding	2007	Modeling the Psychosocial Effects of Terror or Natural Disasters for Response Preparation	Differential Equation
Aziz et. al.	2009	Design of an intelligent support agent model for people with a cognitive vulnerability	Differential Equation
Ting et. al.	2010	A Computational Model of Situation Awareness for MOUT Simulations	Differential Equation and Fist order logic
Fiemke Both, Mark Hoogendoorn, Michel	2010	Computational Modeling and Analysis of Therapeutical	Differential Equation

C.A. Klein, and Jan Treur		Interventions for Depression	
Naze and Treur	2011	A Computational Agent Model for Post-traumatic stress disorder	Differential Equation and First order logic
Bosse et. al.	2011	Incorporating Human Aspects in Ambient Intelligence and Smart Environments	Rule Base
Azizi Ab Aziz	2011	Exploring Computational Models for Intelligent Support of Persons with Depression	Differential Equation
Jan Treur	2011	Dreaming Your Fear Away: a Computational Model for Fear Extinction Learning During Dreaming.	Differential Equation
Ahmad and Zaid	2012	A Mood Driven Computational Model for Gross Emotional Regulation Paradigm	Differential Equation
Dilhan J. Thilakarathne, Jan Treur	2013	A computational cognitive model for intentional inhibition of actions.	Symbolic frame work
Jeffrey B. Vancouver, Justin M. Weinhardt , Ronaldo Vigo	2014	Change one can believe in: Adding learning to computational models of self-regulation	Rule base

2.8 Evaluation Methods in Computational Modeling

In order to evaluate the formal model (computational model), there are two techniques were used to verify the correctness of the model which are mathematical verification and automated verification (Both, Hoogendoorn, Klein, & Treur, 2008; Ting, Zhou, & Hu, 2010;Bosse, Pontier, & Treur, 2010).

2.8.1 Mathematical Verification

Mathematical analysis is one of the important aspects to determine in which stable situation for the proposed model are possible. Equilipria are analyzed that may occur under certain conditions. The equilibria describe situations in which a stable situation has been reached and these equilipria conditions are interesting to be discovered, it is possible to explain equilibria conditions using knowledge from the theory or problem that is modeled. In addition, the existence of reasonable equilibria is also an indication for the correctness of the model. Moreover, if the dynamic of the system is described by differential equation, then the equilibria can be estimated by setting a derivation (or all derivatives) to zero. One important thing to be noted, an equilibria condition is considered stable if the system always returns to it after small disturbance. For instance, using this autonomous equation,

$$dy/dx = f(y) \qquad \textit{Eq.1}$$

The equilibria or constant solution of this differential equation are the roots of the equation

$$f(y)=0 \qquad \text{Eq.2}$$

2.8.2 Automated Verification

In order to verify whether the model indeed generates results that adherence to psychological literatures, a set of properties should be identified from related literatures. After that, these properties should be specified by a language called Temporal Trace Language (TTL). TTL is built on atoms to states of the world, time points, and traces. This relationship can be presented as *holds(state (γ, t), p) or state(γ, t)* |= *p*, which means that state property *p* is true in the state of trace *γ* at time point *t* (Bosse, Jonker, Van der Meij, Sharpanskykh, & Treur, 2009). It is also comparable to the *Holds*-predicate in the Situation Calculus. Based on that concept, dynamic properties can be formulated using a hybrid sorted predicate logic approach, by using quantifiers over time and traces and first-order logical connectives such as $\neg$, $\wedge$, $\vee$, $\Rightarrow$, $\forall$, and $\exists$.

2.9 Summary

This chapter had shown the important concepts of victim's stress during natural disasters and answered the questions why individuals get stress while facing stressful situations such as natural disasters. Obviously, all approaches have identified the need to develop a formal model (computational model) of victim's stress. Next chapter explains the research methodology adopted to build a computational model.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter shows the methodology that has been adopted in this study. The methodology involves six (6) phases of design plan to explore the psychological, cognitive process in victim's stress during natural disaster in order to develop a computational model of victims' stress and end up with evaluation phase. Figure 3.1 explains the phases are involved to achieve the goal of this study.

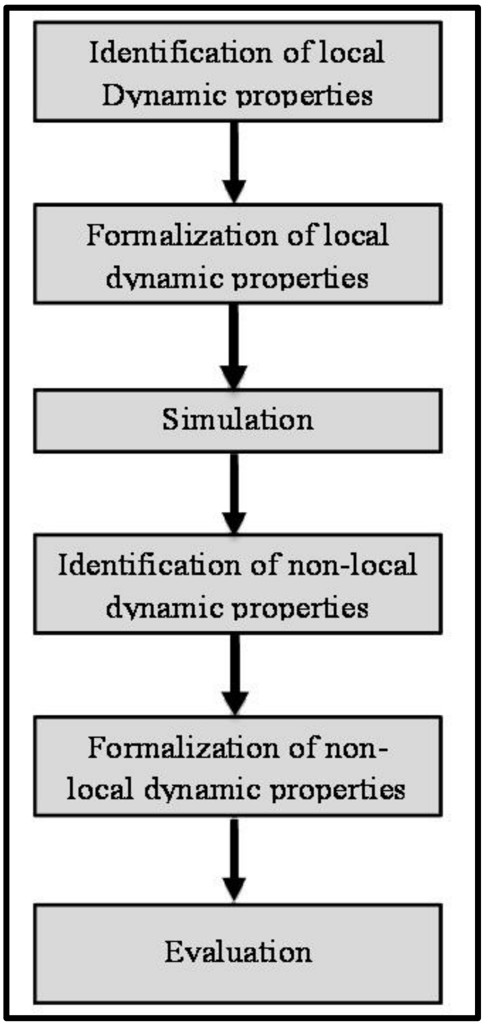

Figure 3.1: Research Methodology for Cognitive Modeling (Aziz, 2010)

The below sections will describe these phases:

3.2 Phase 1: Identification of Local Dynamic Properties

In this phase, local dynamic properties will be identified from past literatures. Local dynamic properties are factors that contribute directly or indirectly to victim's stress during natural disaster (normally these factors will be in informal representations). A set of important properties (i.e., twenty four) that later used to formalize the concepts in victims' stress were the outcome from this phase. Figure 3.2 is an example of local dynamic properties.

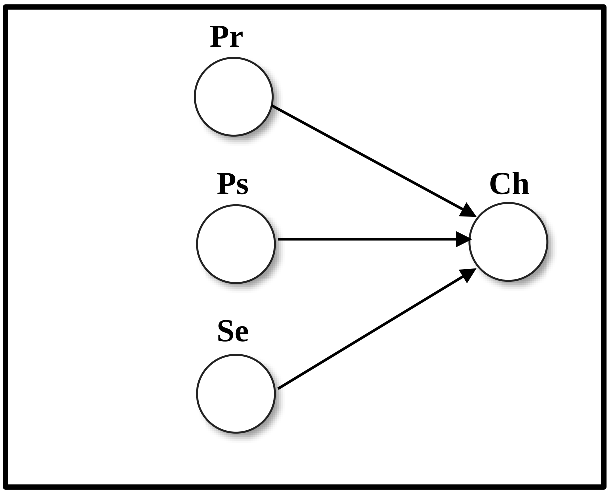

Figure 3.2: An example of local properties

In Figure 3.2, *Pr* (personal resources), *Ps* (positive personality), *Se* (stressful event), and *Ch* (challenge) are examples of local dynamic properties which used in upcoming phase to be in formal representations.

For the sake of clarity, we classify all these local dynamic properties into three classifications, depending upon the relation among these factors, include external, instantaneous, and temporal relationship. Table 3.1 shows the external factors of local dynamic properties. Table 3.2 and table 3.3 illustrate temporal and instantaneous local properties respectively.

Table 3.1: Local Dynamic Properties with External Relationship

No.	Local Dynamic Properties	Formal Representation	Description
1	Imminence of harm	*Ih*	Refers to a condition before occurring harm which participate to rise harm
2	Perceive of harm	*Ph*	It will be from the environment in concurrent with stressful event
3	Stressful event	*Se*	Refers to any disastrous event such as Natural disaster
4	Social support	*Sc*	Any kind of assistance and encouragement for individual during stressful event
5	Personal Resources	*Pr*	Valuable resources such as condition, object, energy and individual attributes
6	Experiences	*Ep*	Experiences of an individual in facing a stressful event
7	Pos. Personality	*Ps*	Refers to negative and positive personality

Table 3.2: Local Dynamic Properties with Temporal Relationship

No.	Local Dynamic Properties	Formal Representation	Description
1	Coping Skills	*Cs*	An existing skills of an individual to cope with stressful event
2	Exhaustion in Coping	*Ex*	A condition when individuals feel unsatisfied after coping
3	Resilience	*Rs*	Resilience refers to an individual's tendency to cope with stressful event or any adversity
4	Long Term Stress	*Ls*	How human body respond to any kind of stressful situation that happens for a long period

Table 3.3: Local Dynamic Properties with Instantaneous Relationship

No.	Local Dynamic Properties	Formal Representation	Description
1	Challenge	*Ch*	A willingness to undertake change and face new activities
2	Threat	*Th*	Refers to the condition when damage maybe occurs
3	Harm	*Hm*	A condition when damage has already occurred
4	Commitment	*Cm*	The tendency to involve oneself in what one encounters
5	Control	*Cl*	The tendency of an individual to believe that no matter how bad things get, the person needs to keep trying to overcome over stressful event
6	Acceptance	*Ap*	Individuals' condition when they are trying to face the stressful event in a trial to change the situation
7	Holdback	*Hb*	The opposite case of acceptance when individuals give up and no longer trying to face a stressful event
8	Hardiness	*Hd*	an existential courage to deal with stressful event
9	Short term stress	*Ss*	How human body respond to any kind of stressful situation that happens instantaneously
10	Problem Focus	*Pf*	Refers to an interpersonal efforts of an individual to alter the situation as well as rational efforts to get the problem solved
11	Emotional Focus	*Ef*	Refers to an entail efforts of an individual to control the emotional consequences of stressful event (thinking rather than acting)
12	Ability to cope	*Ac*	Capability of an individual to cope through encountering stressful event
13	Normal level of Experiences	EP_{norm}	The initial setting of experiences within individuals

3.3 Phase 2: Formalization of local Dynamic Properties

In this phase, a formal model has been formulated on the basis of the underlying mechanism obtained from previous phase (Phase I). This formal model aims to be in term of executable dynamics properties to create executable model of the dynamic of the process. In regarding to the model, there are seven main components are interacting together. These components are gathered as, individual attributes, resources, predisposed factor, appraisal, resilience, coping, and stress. Differential equation technique was used to represent the formalization of local dynamic properties.

3.3.1 Appraisal Properties

The following sections explain the formalization of appraisal factors which includes challenge, threat, harm, acceptance, holdback as well as imminence of harm (Ih) from external factors.

1) Challenge (Ch)

Ch is a local dynamic property which is used to express how an individual appraised the stressful event (*Se*) and personal resources (*Pr*) as a challenge and it is influenced by high level of positive personality (*Ps*). Figure 3.3 shows how *Ch* is triggered by *Se*, *Pr*, and *Ps*. *Ch* can be represented as a mathematical equation as provided below in Eq. 3.

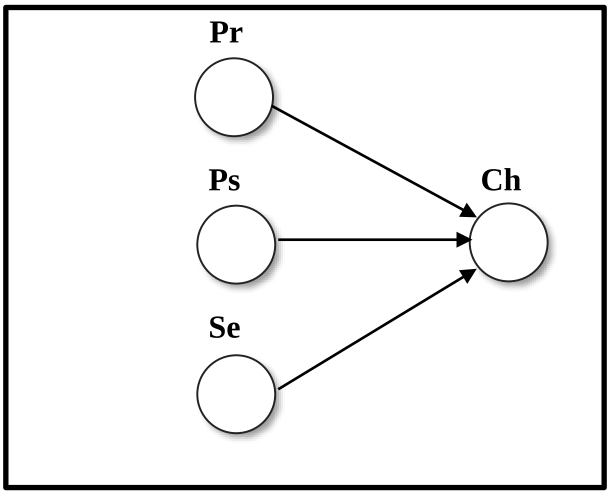

Figure 3.3: Challenge

$$Ch(t) = \lambda_{ch}.Ps(t) + (1 - \lambda_{ch}) . [1 - (Se(t).(1 - Pr(t)))].Ps(t) \quad \text{Eq.3}$$

The input for this equation is three elements which are *Pr*, *Ps*, and *Se*. *Ch* is the output of this equation. *Ch* occurs when *Pr* and *Se* are triggered and also high level of positive personality should be triggered. Parameter λ is used to control or regulate the equation. Table 3.3 illustrates the effect on *Ch* when the input conditions are changed.

Table 3.4: Different Conditions of Challenge

Conditions	Local dynamics properties	Challenge Value	Description
Condition 1	Ps high Pr high Se high	Ch high	Ch is high when a local property Ps is high. Pr and Se are also playing important role.
Condition 2	Ps high Pr low Se high	Ch high	
Condition 3	Ps low Pr low Se low	Ch low	

2) Threat (Th)

Another local dynamic property is threat. It is another condition which influenced by stressful event (Se), personal resources (Pr) and positive personality (Ps). Th occurs with low level of positive personality (Ps) as well as the fluctuated level of personal resources and stressful event. Figure 3.4 illustrates how threat is triggered by stressful event, personal resources, and positive personality. Th can be represented as a mathematical equation as provided below in Eq.4.

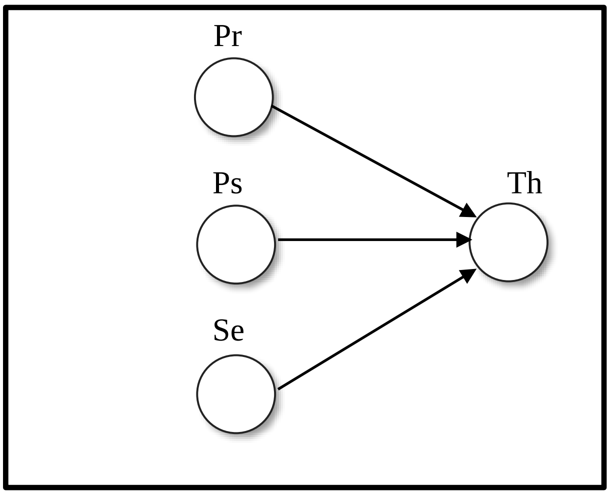

Figure 3.4: Threat

$$Th(t) = [\ \omega_{th}.Se(t) + (\ 1- \omega_{th}).(1- Pr(t)\ )\ .\ Se\ (t)\ ]\ \ .\ (\ 1 - Ps(t)) \qquad \text{Eq.4}$$

The input for this equation is same ingredients with previous local dynamic property (Ch) which are personal resources (Pr), stressful event (Se), and positive personality (Ps). Th is the output from this equation. Parameter ω is used to control or regulate the equation. Table 3.5 illustrates the effect on Th when the input conditions are changed.

Table 3.5: Different Conditions of Threat

Conditions	Local Dynamics Properties	Threat Value	Description
Condition 1	Ps high Pr high Se high	Th low	Th is high when a local property Ps is low and vice versa.
Condition 2	Ps high Pr low Se high	Th low	
Condition 3	Ps low Pr low Se low	Th high	

3) Harm (Hm)

It is another property whereas experience of harm or loss refers to a condition where damage has already occurred, but an anticipated one (imminence of harm). This can be the injury or loss of valued persons. Harm is triggered by four ingredients which are imminence of harm (Ih), stressful event (Se), personal resources (Pr), and positive personality (Ps). Harm occurs when imminence of harm and/or stressful event are high. Figure 3.5 shows how harm is triggered by Se, Pr, Ps, and Ih. It can be represented in a mathematical equation as provided below in Eq.5. Table 3.5 illustrates the effect on Hm when the input conditions are changed.

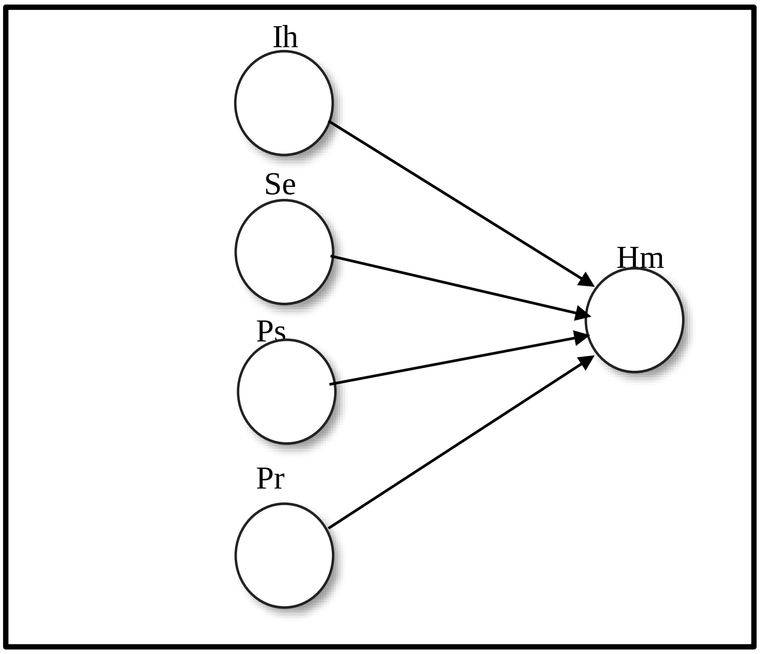

Figure 3.5: Harm

$$Hm(t) = [\, 1 - (\beta_{hm}.\, Ps(t) + (1 - \beta_{hm})\, Pr(t))\,]\, .\, [\eta_{hm}\, .Se(t) + (1-\eta_{hm}).\, Ih(t)] \qquad \text{Eq.5}$$

The input for this equation is four elements which are imminence of harm (Ih), stressful event (Se), personal resources (Pr), and positive personality (Ps). All these

Parameter β is used to control or regulate the equation. Table 3.6 illustrates the effect on Hm when the input conditions are changed.

Table 3.6: Different Conditions of Harm

Conditions	Local Dynamics Properties	Harm Value	Description
Condition 1	Ps high Pr high Se high Ih high	Hm high	Hm is high when a local properties Ih and/or Se are high.
Condition 2	Ps high Pr low Se low Ih high	Hm high	
Condition 3	Ps low Pr low Se high Ih low	Hm low	

4) Imminence of Harm (Ih)

Ih is an external factor that represented a local dynamic property. It is triggered by two factors which are coping skills (Cs) and perceive of harm (Ph) (will be from the environment). Ih occurs with high level of perceiving the harm and low level of coping skills. Figure 3.6 illustrates how imminence of harm will be triggered by coping skills and perceive of harm. Ih can be represented in a mathematical equation as provided below in Eq.6.

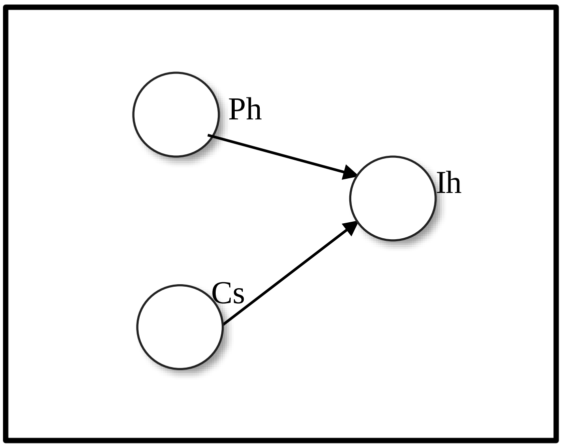

Figure 3.6: Imminence of Harm

$Ih(t) = Ph(t) .(1- Cs(t))$ Eq.6

This is a differential equation of imminence of harm which has two inputs perceive of harm (Ph) (from environment) and coping skills (Cs).Ih is the output from this equation. Ih occurs with high level of perceive of harm and low level of coping skills. Table 3.6 illustrates the effect on Ih when the input conditions are changed.

Table 3.7: Different Conditions of Imminence of Harm

Conditions	Local Dynamics Properties	Imminence Of Harm Value	Description
Condition 1	Ph high Cs low	Ih high	Imminence of harm is high when perceive of harm is high and vice versa
Condition 2	Cs low Ph low	Ih low	

5) Acceptance (Ap)

Ap is a local dynamic property which refers to individuals' perception when they are facing stressful circumstances. Individuals often are trying to change the situation by appraise it as a challenge (that means, high level of acceptance). Ap is triggered by two ingredients which are challenge (Ch) and Harm (Hm). The level of acceptance will be affected (increases) when an individual appraise or evaluate the event as a challenge (Hm) with a small proportion of harm (Hm). Figure 3.7 illustrates how acceptance will be triggered by challenge and harm. Ap can be represented in a mathematical equation as provided below in Eq.7.

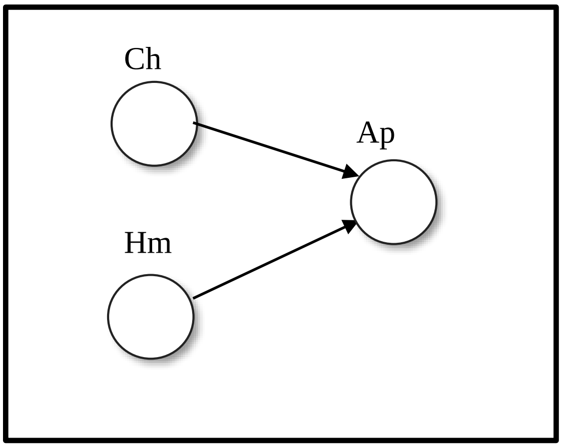

Figure 3.7: Acceptance

$$Ap(t) = Ch(t) .(1 - Hm(t)) \qquad \text{Eq.7}$$

This is a differential equation of acceptance which has two inputs Ch and Hm. The output is Acceptance. Table 3.7 illustrates the effect on acceptance when the input conditions are changed.

Table 3.8: Different Conditions of Acceptance

Conditions	Local Dynamics Properties	Acceptance Value	Description
Condition 1	Ch high Hm high	Ap high	Although a small portion of Hm will take a role, Ap is high when a local property Ch is high and vice versa.
Condition 2	Ch low Hm high	Ap low	

6) Holdback (Hb)

Holdback is the opposite condition with previous local dynamic property (acceptance). It is a negative evaluation or appraisal to the stressful circumstances, that's mean, individuals will give up and not trying to change the situation. It is triggered by two ingredients which are threat (Th) and harm (Hm). Hb occurs when individuals appraise the event as a threat or harm (high level of threat or harm leads to holdback). Figure 3.8 illustrates how holdback will be triggered by threat and harm. Moreover, holdback can be represented as a mathematical equation as provided below in Eq.8.

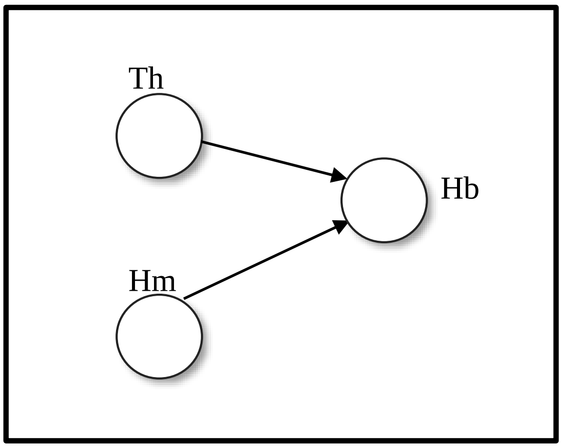

Figure 3.8: Holdback

$$Hb(t) = \mu_{hb}.Th(t) + (1-\mu_{hb}).Hm(t) \quad \text{Eq.8}$$

This differential equation has derived to calculate the value of holdback. The inputs are threat and harm. Holdback can result when anyone of the inputs (Hm or Th) is triggered. Parameter μ is used to control the equation. Table 3.8 illustrates the effect on holdback when the values of harm and threat are changed.

Table 3.9: Different Conditions of Holdback

Conditions	Local Dynamics Properties	Holdback Values	Description
Condition 1	Th high Hm high	Hb high	Hb is high whenever one or two of local property is high. (i.e. Th or/and Hm are high)
Condition 2	Th low Hm high	Hb high	
Condition 3	Th low Hm low	Hb low	

Figure 3.9 shows how appraisal ingredients are triggered and the relationships among these elements as well as the effect of imminence of harm.

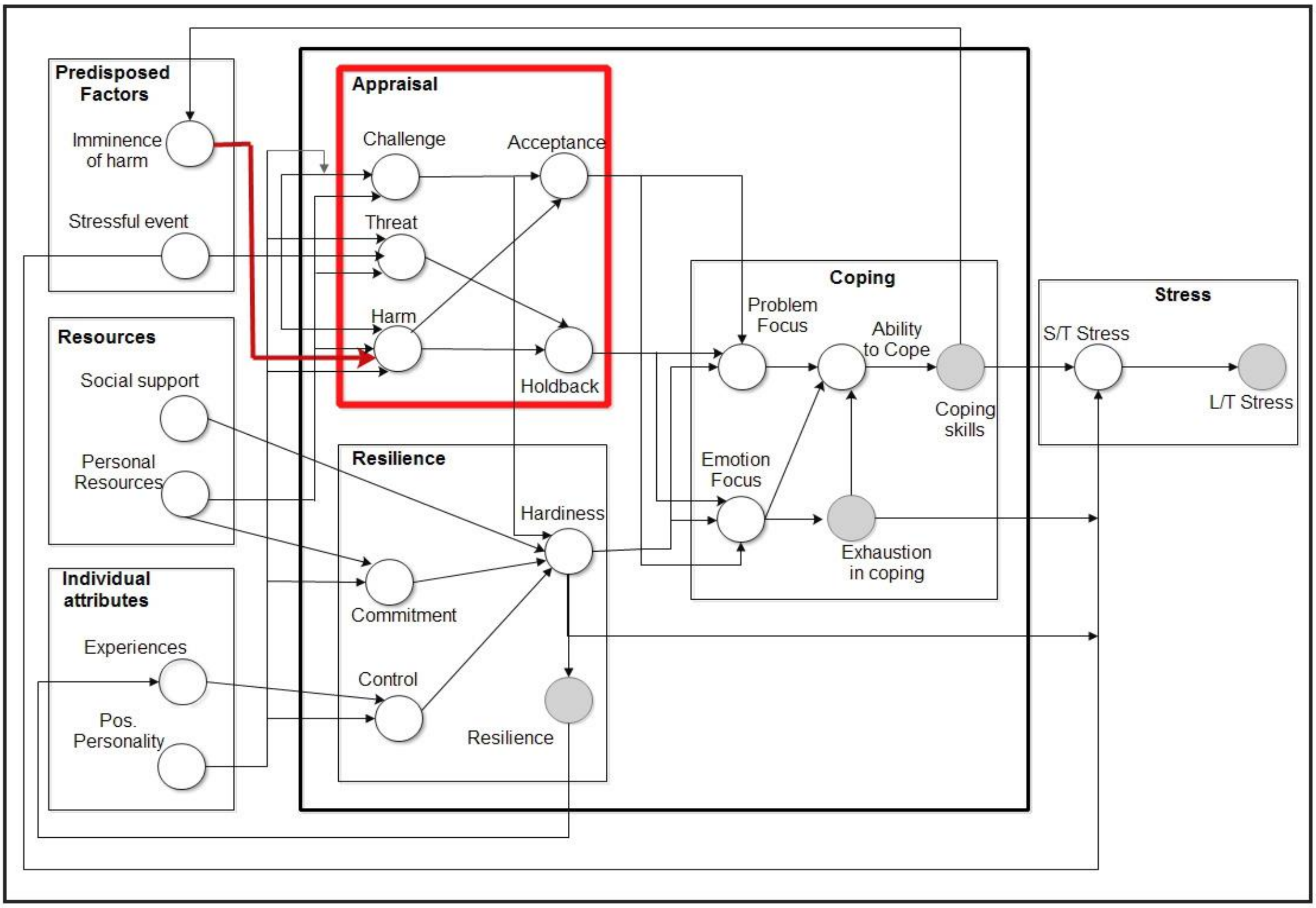

Figure 3.9 Appraisal Factors and Imminence of Harm

3.3.2 Resilience Properties

The following sections explain the formalization of resilience factors which includes commitment (Cm), control (Cl), hardiness (Hd), and resilience (Rs). As well as experiences (Ep) from external factors.

1) Commitment (Cm)

Commitment refers to the belief that whatever bad things get, it is essential to remain involved with the situation rather than sink in alienation. Moreover, Cm is an essential part in increasing the existing courage of individuals to face the stressful event. Commitment is triggered by personal resources (Pr) and Positive personality (Ps). Cm occurs when Pr or/and Ps is triggered. Figure 3.9 illustrates how commitment is triggered by personal resources and positive personality. Commitment has represented in a mathematical expression as provided below in Eq.9.

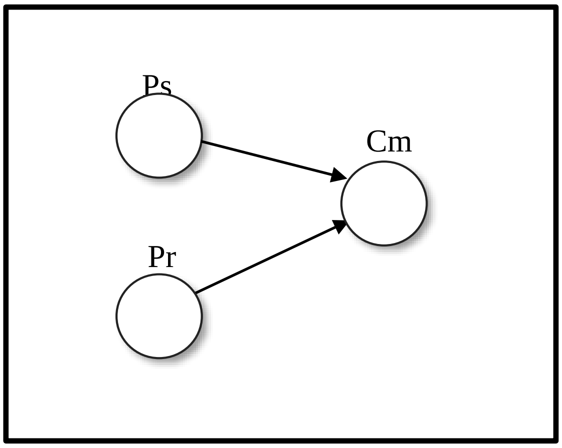

Figure 3.10: Commitment

$$Cm(t) = \alpha_{cm}.Ps(t) + (1-\alpha_{cm}).Pr(t) \qquad \text{Eq.9}$$

Commitment is measured by using the inputs values of Ps and Pr. Cm's value will be affected by Ps and/or Pr. Parameter α is used to control the equation. Table 3.9 shows the value of commitment when the input values are changed.

Table 3.10 Different Conditions of Commitment

Conditions	Local Dynamics Properties	Commitment Value	Description
Condition 1	Ps high Pr high	Cm high	Cm is high when anyone of local properties Ps and/or Pr is high.
Condition 2	Ps low Pr low	Cm low	
Condition 3	Ps high Pr low	Cm high	
Condition 4	Ps low Pr high	Cm high	

2) Control (Cl)

Control refers to a condition when individuals believe that they can influence the event and turn it into growth opportunities. Moreover, Cl is an essential part in increasing the existing courage of individuals to face the stressful event (playing same role with commitment in term of increasing the existing courage). Cl is triggered by experiences (Ep) and positive personality (Ps). Figure 3.10 shows how control will be triggered by experiences and positive personality. It can be represented by a mathematical expression as provided below in Eq.10.

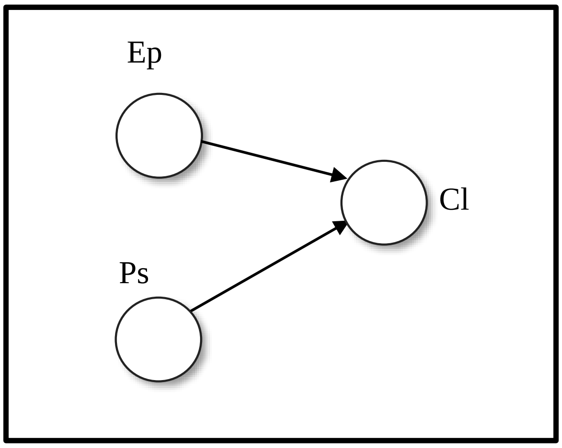

Figure 3.11: Control

$Cl(t) = \beta_{cl}.Ps\,(t) + (1-\beta_{cl}).Ep(t)$ Eq.10

In regard to the equation of control, it has two inputs which are determined the value of control. Anyone of the inputs can increase the value of control (*Ps* and/or *Ep*). Parameter β is chosen to control the equation (no less than zero and no more than one).

Table 3.11: Different Conditions of Control

Conditions	Local Dynamics Properties	Control Value	Description
Condition 1	Ps high Ep high	Cl high	Cl is high when anyone of local properties Ps and/or Ep is high.
Condition 2	Ps low Ep low	Cl low	
Condition 3	Ps high Ep low	Cl high	
Condition 4	Ps low Ep high	Cl high	

3) Experiences (Ep)

Ep refers to the experiences of individuals in facing stressful circumstances. It is playing important role with resilience to explain why individuals response to stressful event differently. Figure 3.11 shows how Ep is triggered by resilience. It can be represented in a mathematical expression as provided below in Eq. 11.

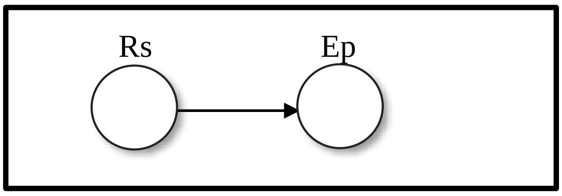

Figure 3.12: Experiences

$$Ep(t) = \lambda_{ep}.Ep_{norm}(t) + (1- \lambda_{ep}).Rs(t) \qquad \text{Eq.11}$$

Ep is measured mathematically using the proportional contribution of experiences (Ep_{norm}) baseline which represents the initial setting of experiences within an individuals and resilience (Rs). In order to control or regulate the equation, parameter λ is used. Table 3.11 shows the different condition of experiences when inputs are changed.

Table 3.12: Different Conditions of Experiences

Conditions	Local Dynamics Properties	Experiences Value	Description
Condition 1	Rs high	Ep high	Ep is high when Rs is high and vice versa.
Condition 2	Rs low	Ep low	

4) Hardiness (Hd)

Another prevalence factor for a person with stress is hardiness. Hd represents the existential courage within an individual to deal with a stressful event. It is reported in some cases with essential role in turning stressful circumstances from potential disasters into growth opportunities (Maddi, 2006; S. R. Maddi, 2013). Typically, there are three components of hardiness attitudes which involve challenge, commitment, and control. Moreover, all of these three ingredients should be strong enough in order to constitute high level of hardiness. According to (Eschleman et al., 2010), Social support is another factor that triggers hardiness positively (positive relationship between hardiness and social support). Figure 3.12 illustrates how hardiness is triggered by commitment (Cm), control (Cl), challenge (Ch), and social support (Sc). It can also be represented in a mathematical expression as provided below in Eq.12.

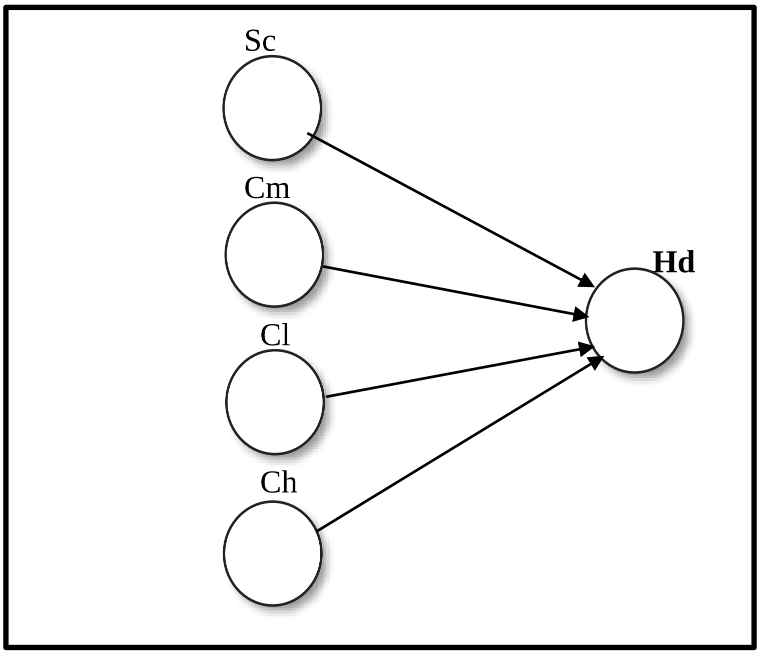

Figure 3.13: Hardiness

$Hd(t) = \omega_{h1}.Sc(t) + \omega_{h2}.Cm(t) + \omega_{h3}.Ch(t) + \omega_{h4}.Cl(t)$ Eq.12

Where $\sum_{4}^{i=1} \omega\ hi = 1$, (i.e., ω h1 + ω h2+ ω h3+ ω h4=1)

This equation of hardiness has four inputs (Sc, Cm, Cl, and Ch), and the output is Hd. All of these four inputs are affected equally to determine the level of hardiness within an individual. To regulate the equation, parameter (ωhi) is used whilst the summation of (ωhi) is always equal to one. Table 3.12 shows the condition of hardiness when the input values are changed.

Table 3.13: Different Conditions of Hardiness

<table>
<tr><th>Conditions</th><th>Local Dynamics Properties</th><th>Hardiness Value</th><th>Description</th></tr>
<tr><td>Condition 1</td><td>Sc high
Cl high
Cm high
Ch high</td><td>Hd high</td><td rowspan="3">Hd is high when a local properties Sc, Cl, Ch, Cm are high and vice versa</td></tr>
<tr><td>Condition 2</td><td>Sc high
Cl low
Cm high
Ch low</td><td>Hd high</td></tr>
<tr><td>Condition 3</td><td>Sc low
Cl low
Cm low
Ch low</td><td>Hd low</td></tr>
</table>

5) Resilience (Rs)

Rs is the concept that has been initiated to explain the process of adapting well in facing the trauma or any kind of adversity. Temporal Resilience is caused when hardiness (Hd) is high and persists for a long period. Figure 3.13 explains how resilience is triggered by hardiness. It can be represented by a mathematical equation as provided below in Eq.13.

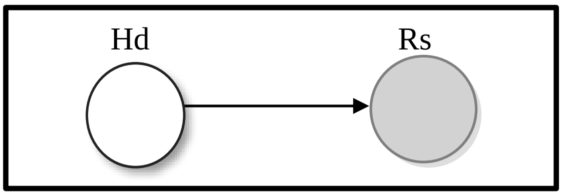

Figure 3.14: Resilience

$$Rs(t + \Delta t) = Rs(t) + \kappa_{rs}.(1-Rs(t)). [Hd(t) - Rs(t)]. Rs(t). \Delta t \quad \text{Eq.13}$$

Rs increases and decreases over time. When Hd is higher than Rs and multiplied with contribution parameter, κ_{rs}, Rs increases. If not, it decreases depending on its previous level and contribution factor. In order to determine the changing process, time interval between (t) and *(t + Δt) is* used. Table 3.13 shows how resilience will affect when input value of hardiness is changed.

Table 3.14: Different Conditions of Resilience

Conditions	Local Dynamics Properties	Resilience Value	Description
Condition 1	Hd high	Rs high	Rs is high when Hd is high and vice versa
Condition 2	Hd low	Rs low	

In figure 3.10 below, all components of resilience part as well as experiences from external factors that have been illustrated above.

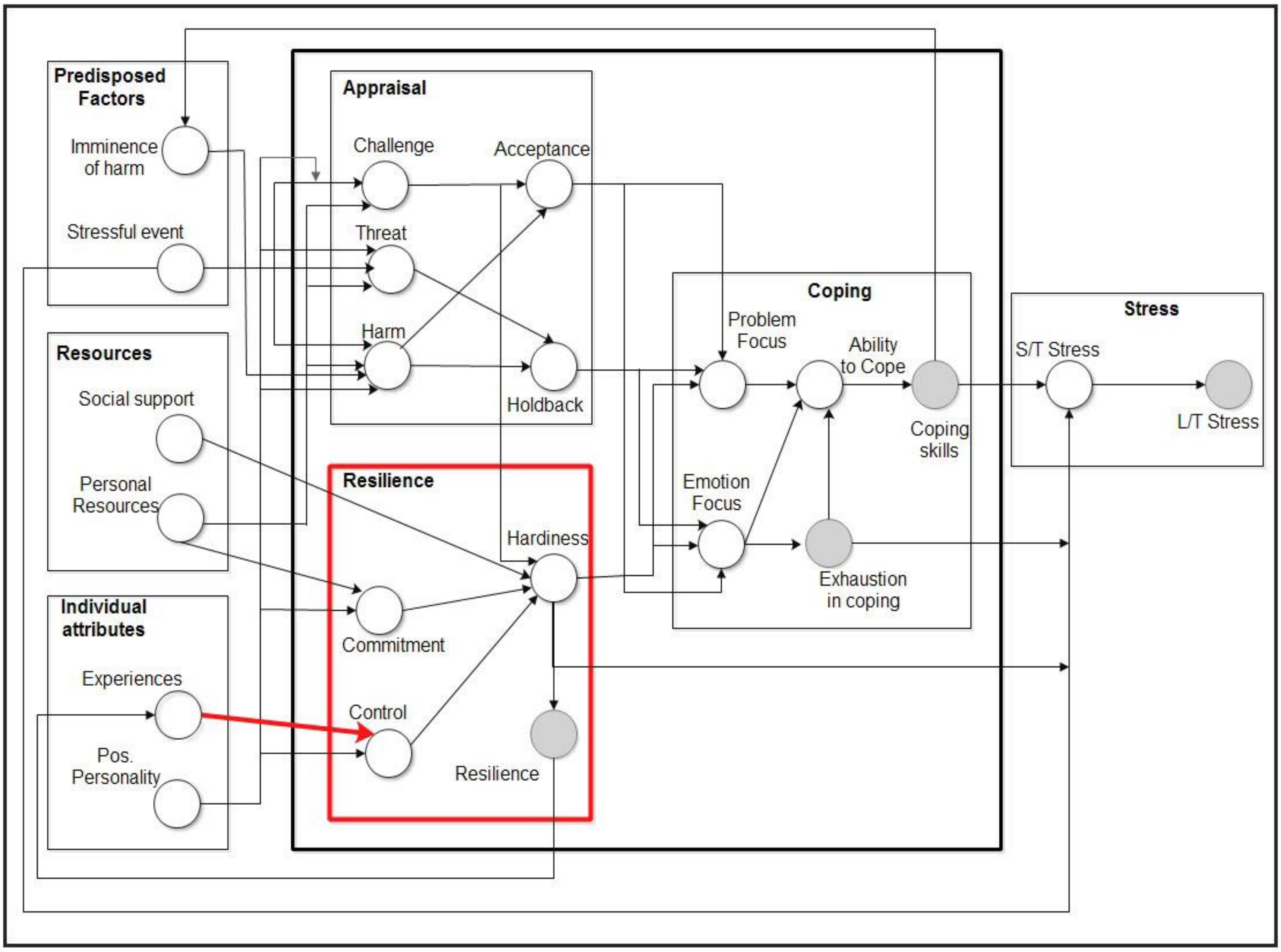

Figure 3.15: Resilience Factors and Experiences

3.3.3 Coping Properties

1) Problem Focus Coping (Pf)

Problem focus coping strategy refers to interpersonal endeavors to change the stressful situation as well as rational efforts to get the problem solved (the opposite of holdback, acting rather than thinking). It is triggered by three factors which are acceptance (Ap), Holdback (Hb), and hardiness (Hd). High level of acceptance with positive effect of hardiness will increase the level of problem focus coping; otherwise, it will decrease (high level of holdback). Figure 3.14 is used to illustrate how Pf is triggered by Hd, Hb, and Ap. It can be represented in a mathematical equation as provided below in Eq.14.

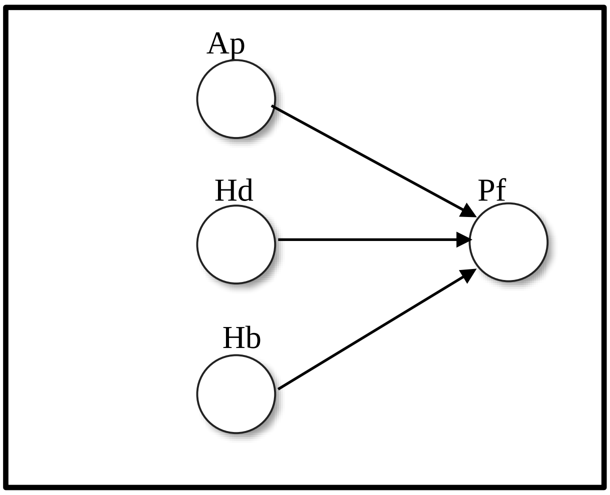

Figure 3.16: Problem Focus

$$Pf(t) = (1 - Hb(t)) \cdot [\beta_{Pf} \cdot Ap(t) + (1 - \beta_{Pf}) \cdot Hd(t)] \quad \text{Eq.14}$$

Pf is measured using the contribution rate which determines by β_{Pf} of acceptance (Ap) and hardiness (Hd). Problem focus will be chosen if there is low level of holdback. To regulate the equation, parameter β_{Pf} is used. Table 3.14 illustrates the conditions of problem focus when inputs values are changed.

Table 3.15 Conditions of Problem Focus

Conditions	Local Dynamics Properties	Problem Focus Value	Description
Condition 1	Ap high Hd high Hb low	Pf high	Pf is high if one of the local dynamic properties Hd, Ap is high multiplied by low level of holdback (Hb) and vice versa
Condition 2	Ap low Hd low Hb high	Pf low	

2) Emotional Focus Coping (Ef)

The concept of emotional coping refers to associated endeavors to control the emotional consequences of potential stressful event (thinking rather than behaving to change individual –environment relationship). The occurrence of emotional focus is determined according to the level of hardiness (Hd), holdback (Hb), and acceptance (Ap). Figure 3.15 explains how emotional focus is triggered by Hd, Hb, and Ap. In addition to this, it can be represented in a mathematical expression as provided below in Eq.15.

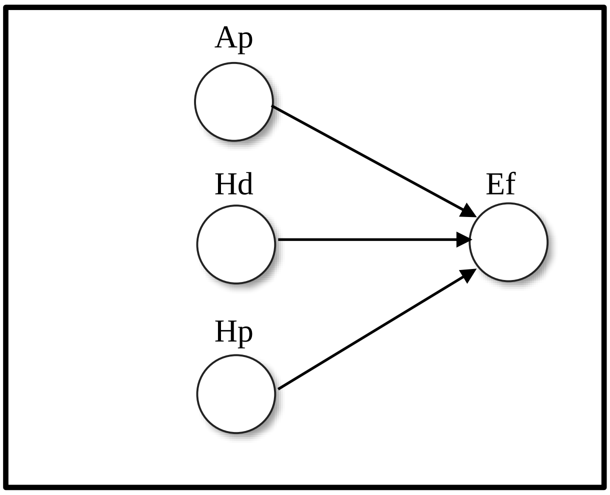

Figure 3.17: Emotional Focus

$$Ef(t) = Hb(t).\ [(1-\ [\ \alpha_{Ef}.Ap(t) + (1 - \alpha_{Ef}).Hd(t)\ ]\ ) \qquad \text{Eq.15}$$

Ef is measured using the contribution rate which determines by α_{Ef} of acceptance (Ap) and hardiness (Hd). Emotional focus will be chosen if there is high level of holdback. To regulate the equation, parameter β_{Pf} is used. Table 3.15 illustrates the conditions of problem focus when inputs values are changed.

Table 3.16: Different Conditions of Emotional Focus

Conditions	Local dynamics properties	Emotional focus Value	description
Condition 1	Ap low Hd low Hb high	Ef high	Ef is high if one of the local dynamic properties Hd, Ap is high multiplied by low level of holdback (Hb) and vice versa
Condition 2	Ap high Hd high Hb low	Ef low	

3) Ability to Cope (Ac)

Ac refers to capability of an individual to cope through encountering disastrous event. It is determined by the composition of three ingredients which are problem focus (Pf), emotional focus (Ef), and exhaustion in coping (Ex). The level of Ac increases when problem focus will be chosen. In addition to this, there is slight effect to increase the level of Ac by Ex and Ef. Figure 3.16 illustrates how Ac will be triggered by Ex, Ef, and Pf. It can be expressed by a mathematical equation as provided below in Eq.16.

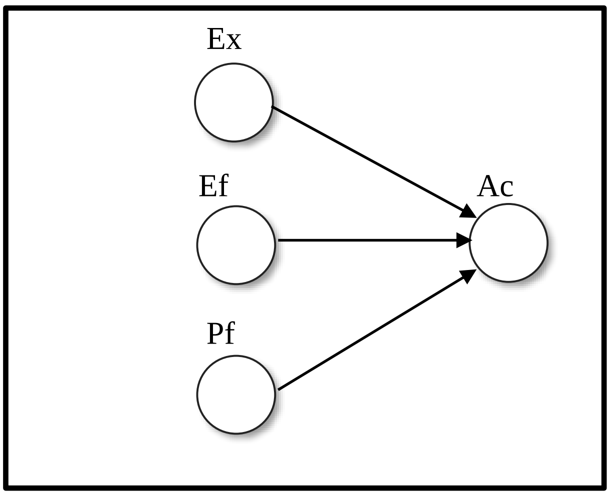

Figure 3.18: Ability to Cope

$Ac(t) = w_{ac1}.Pf(t) + w_{ac2}.Ef(t) - \mu_{ex}\, Ex(t)$ Eq.16

Where $\sum_{4}^{i=1} \omega\ aci = 1$

This differential equation explains how Ac will be affected. Parameter w_{ac} is introduced in order to control or regulate the equation. Table 3.16 shows the conditions of ability to cope when the input values are changed.

Table 3.16: Different Conditions of Ability to Cope

<table>
<tr><th>Conditions</th><th>Local Dynamics Properties</th><th>Ability to Cope Value</th><th>Description</th></tr>
<tr><td>Condition 1</td><td>Ef high
Ex high
Pf low</td><td>Ac low</td><td rowspan="2">Ability to cope increases when problem focus strategy will be chosen and decreases with high level of exhaustion in coping and emotional coping</td></tr>
<tr><td>Condition 2</td><td>Ef low
Ex low
Pf high</td><td>Ac high</td></tr>
</table>

4) Exhaustion in Coping (Ex)

Ex is an unsatisfactory outcome that individuals often feel after experiencing emotional coping. Exhaustion in coping will increase the long-term stress later. It accused by high level of emotional coping and persists for long period. Figure 3.16 explains how exhaustion in coping will be triggered by emotional coping. It expressed in a mathematical equation as provided below in Eq.17.

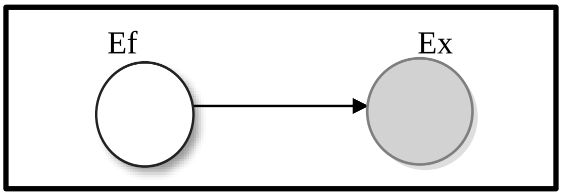

Figure 3.19: Exhaustion in Coping

$Ex(t + \Delta t) = Ex(t) + \mu_{ex}.(1 - Ex(t)). [Ef(t) - Ex(t)]. Ex(t). \Delta t$ Eq.17

Ex increases or decreases over time depending on emotional focus coping (Ef). If there is considerable presence of Ef, the amount of Ex will increase. Parameter μ_{ex} is used to determine the changing Rate of temporal relationship. Moreover, changing process is measured in a time interval between (*t*) and *(t+Δt)*. Table 3.17 shows how the conditions of Ex will be affected when the input values are changed (Ef).

Table 3.18: Different Conditions of Exhaustion

Conditions	Local Dynamics Properties	Exhaustion Value	Description
Condition 1	Ef high	Ex high	Ex is high when Ef is high and vice versa
Condition 2	Ef low	Ex low	

5) Coping skills (Cs)

Cs refers to an existing skill of an individual to cope with stressful event. It occurs when an individual has high level of ability to cope (Ac) and persists for long period (accumulative exposure to Ac will increase upcoming level of Cs). Figure 3.17 shows how coping skills will be triggered by ability to cope. Furthermore, it can be represented in a mathematical expression as provided below in Eq.18.

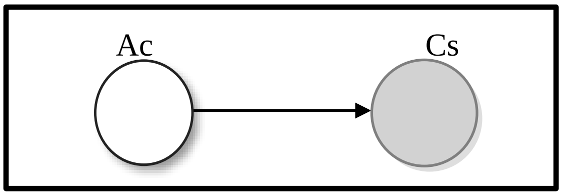

Figure 3.20: Coping Skills

$Cs(t + \Delta t) = Cs(t) + \beta_{cs} .(1- Cs (t)). [Ac(t) – Cs(t)]. Cs(t). \Delta t$ Eq.18

The level of coping skills will increase or decrease over time depending on the level of ability to cope (Ac). Cs will be high if there is considerable presence of Ac. Parameter β_{cs} is used to determine the changing rate of temporal relationship. The changing process is measured in a time interval between (*t*) and *(t+Δt)*. Table 3.18 illustrates how Cs conditions will be affected when the inputs values are changed.

Table 3.19: Different Conditions of Coping Skills

Conditions	**Local Dynamics Properties**	**Coping skills Value**	**Description**
Condition 1	Ac high	Cs high	Cs is high when Ac is high and vice versa
Condition 2	Ac low	Cs low	

All components of coping that have been illustrated above, shown in figure 3.21.

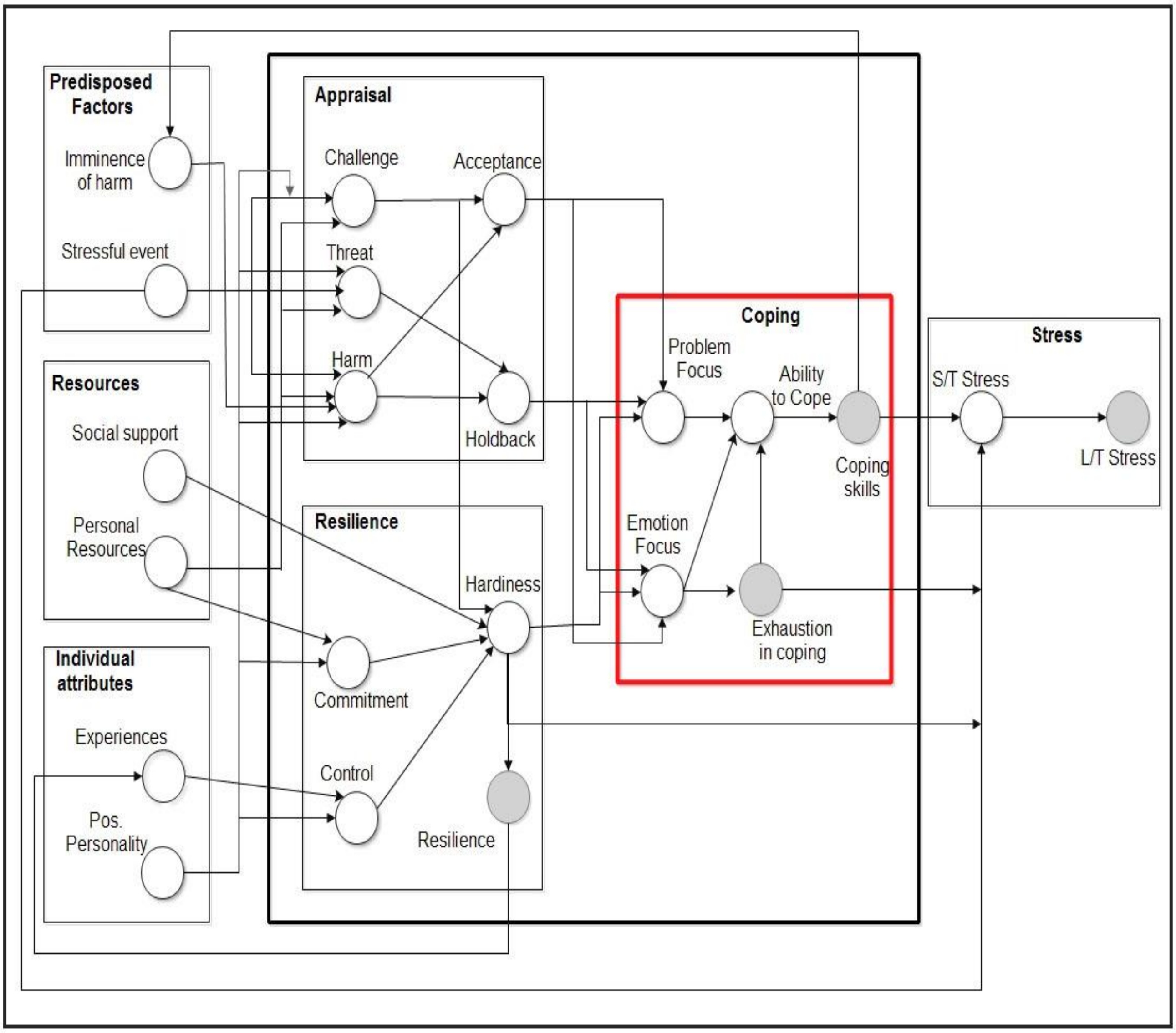

Figure 3.21: Coping Factors

3.3.4 Stress Properties

1) Short term Stress (Ss)

Ss is defined as a reaction to a stressful event or any stimuli that disturbs physical or mental state of individuals instantaneously. In respect to stressful event such as natural disaster, short term stress can be triggered by four ingredients which are hardiness (Hd), Stressful event (Se), exhaustion in coping (Ex), and coping skills (Cs). Figure 3.18 shows how Ss will be triggered. It can also be represented in a mathematical equation as provided below in Eq.19.

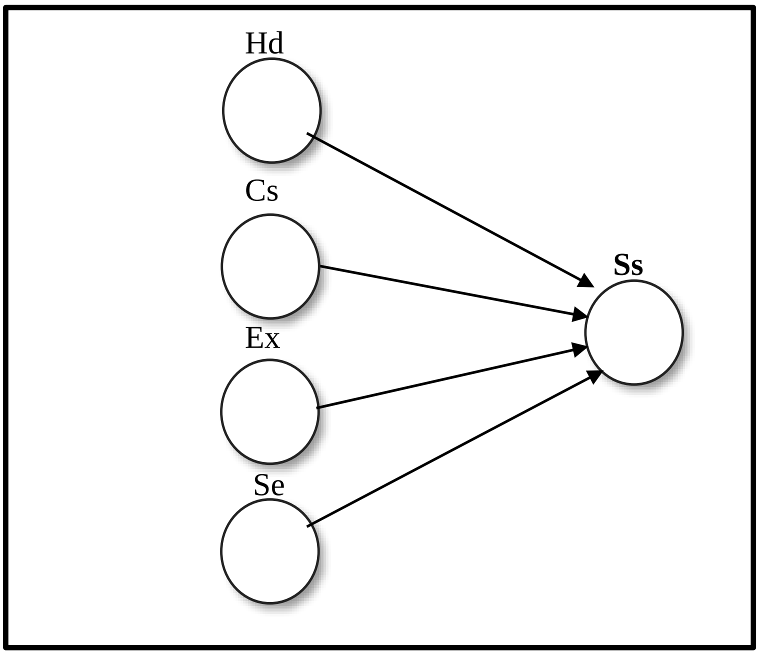

Figure 3.22: Short term Stress

$$Ss(t) = \delta_{ss}. [Se(t). (1 - Cs(t))] + (1 - \delta_{ss}). [Ex(t) . (1- Hd(t))] \quad \text{Eq.19}$$

The differential equation of Ss has four inputs and Ss is the output. Short term stress will be increased when high level of stressful event and exhaustion in coping as well as low level in coping skills and hardiness. Table 3.19 illustrates the conditions of Ss when inputs values are changed.

Table 3.20: Different Conditions of Short term Stress

Conditions	Local Dynamics Properties	Short term Stress Value	Description
Condition 1	Hd high Se high Cs high Ex high	Ss low	Ss is high when a local properties Ex and Se are high as well as low level of Hd and Cs
Condition 2	Hd low Se high Cs low Ex high	Ss high	

2) Long term Stress (Ls)

Long term stress (Ls) is a physical and mental disturbance of individuals for a long period of time after exposure to stressful event. It caused by high level of short term stress (Ss) and continues for long period (accumulative exposure to Ss leads to long term stress). Figure 3.19 explains how Ls will be triggered by short term stress. It can be represented in a mathematical equation as provided below in Eq.20.

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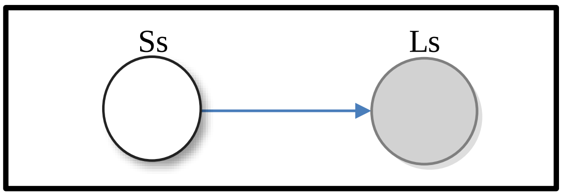

Figure 3.23: Long term Stress

$$Ls(t + \Delta t) = Ls(t) + \zeta_{ls} . (1 - Ls(t)) . [Ss(t) - Ls(t)]. Ls(t). \Delta t \quad \text{Eq.20}$$

The level of Long term stress will be increased or decreased over time depending on the level of short term stress. Long term stress will be in high level if there is considerable presence of short term stress. The changing process is measured in a time interval between (t) and $(t+\Delta t)$. Table 3.20 shows the conditions of Ls when the inputs values are changed.

Table 3.20: Different Conditions of Long term Stress

Conditions	Local Dynamics Properties	Long term stress Value	Description
Condition 1	Ss high	Ls high	Ls is high when Ss is high and vice versa
Condition 2	Ss low	Ls low	

In order to construct a computational model, all these local dynamic properties and their interaction are combined dynamically together (i.e. local properties are linked together to contribute to long term stress). As explained in figure 3.24, individual attributes, resources, and predisposed factors act as external factors which is affect the internal factors (resilience, coping, and appraisal). Finally, the result of these interactions is long term stress. Moreover, must be noted that all nodes are designed in a way to have values ranging from 0 (low) to 1 (high).

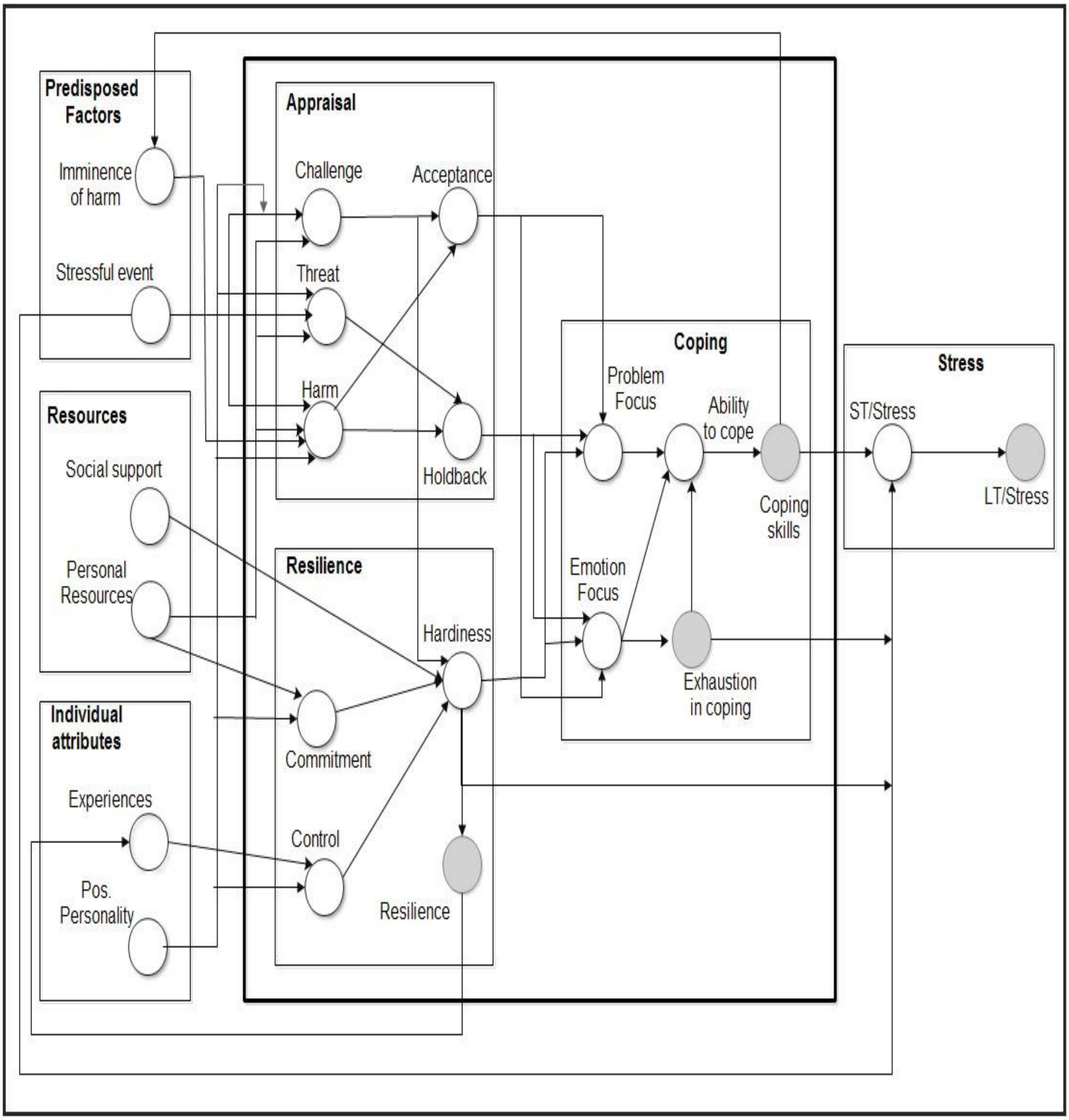

Figure 3.24: Structure of Dynamic Model of Victims' Stress during Natural Disaster

3.4 Phase 3: Simulation

In this phase, the formal model was simulated in order to generate simulation traces by implementing it to three different scenarios; to be precise, person with high level of stress, person with moderate level of stress, and person with low level of stress. Moreover, simulating the computational model provides an insight in the sequences of events over time in specific instances of the process. During this phase, a simulator has designed and developed using matlab programming language. An example of script code that illustrates how the simulation was programmed by using matlab programming is provided below in figure 3.25.

```
%*********************************************************************
*
%                            PART ONE
&
%                       ( initialize parameters)
%
%*********************************************************************
    maxLimY = 1.2;
    Lambda = 0.5;
    Omega =0.5;
    Beta =0.4;
    Mu = 0.5;
    Alpha =0.4;
%*********************************************************************
%*********************************************************************
***
%                            PART TWO
%
%%DECLARE VECTORS FoR ALL NODES and set initial value to external
factors
%*********************************************************************

Ih= zeros(1,numStep);       % Imminence of harm
Se= zeros(1,numStep);       % Stressful event
Sc=zeros(1,numStep);        % Social support
Ps=zeros(1,numStep);        % Positive personality
Ph=zeros(1,numStep);        % perceive of harm FROM environment
Epnorm= zeros(1,numStep);   % Normal experiences level


% declaring initial temporal functions
Cs(1)=0.3;
Ls(1)=0.3;
```

```
for t=1:numStep
Ih(t)=0;          % Imminence of harm

Se(t)=0;          % Stressful event

Sc(t)=1;          % Social support

Pr(t)=1;          % Personal resources

end
% initializing instantaneous functions at time, t=1

 Ch(1) = Lambda * Ps(1) + (1 - Lambda) * (1 -  (Se (1)*(1 - Pr(1))) )
*Ps(1);          % Challenge
 Th(1) = ( Omega* Se(1) + ( 1- Omega )* (1- Pr(1)) * Se(1) )*  (1 -
Ps(1));          % Threat
 Hm(1) = ( 1 - (Beta*Ps(1) + ( 1 - Beta)* Pr(1)) ) * (Beta*Se(1) + (1-
Beta)* Ih(1));    % Harm
 Cm(1) = Alpha*Ps(1) + (1- Alpha)*Pr(1);
% Commitment
 Cl(1)  = Beta* Ps(1) + (1- Beta)* Ep(1);
% control
%**********************************************************************
*
%                             PART Three
&
%                             (Equations)                          %
%**********************************************************************

for t = 2:numStep

 Ih(t)=Ph(t)* (1-Cs(t-1));
 Ep(t)= Zeta* Epnorm (t) + (1- Zeta)* Rs(t-1);

 Ch(t) = Lambda * Ps(t) + (1 - Lambda) * (1 -  (Se (t)*(1 - Pr(t))) )
*Ps(t);             % Challenge
 Th(t) = ( Omega* Se(t) + ( 1- Omega )* (1- Pr(t)) * Se(t) )*  (1 -
Ps(t));               % Threat

end

%**********************************************************************
*
%                              PART four
&
%                             (Plotting)                          %
%**********************************************************************
hold on
t=1:numStep;

subplot(2,1,1);
y = plot(t, Ls,'r:');

xlabel('time steps');ylabel('levels');
xlim([0 numStep]);ylim([minLimX maxLimY]);
hold off;
```

Figure 3.25: An example of Simulation Code

As we mentioned above, the code has been implemented using matlab programming language. For the sake of clarity, this code was divided into four sections. First part, several parameters were initialized which used to regulate the equations. Second part, declared all factors that used in the model and initialized with specific value in order to pass these values to the third part which involved all equations and its operations. After giving initial values to all instantaneous and temporal factors, part four was implemented by plotting the values to generate simulation traces. More discussion and explanation of simulation phase as provided in chapter four.

3.5 Phase 4: Identification of Non-local Dynamic Properties

During this phase, non-local dynamic properties were identified from past literature review (Five different cases are used as a non-local properties). The aim from identifying these non-local dynamic properties is to illustrate the process from an external perspective instead of its cognitive states. These non-local dynamic properties were established by combining the local dynamic properties together. However, more discussion has made in chapter four to explain the findings of this phase.

3.6 Phase 5: Formalization of Non-local Dynamic Properties

These non-local dynamic properties have been formalized in term of global dynamic properties existed in literature. Meanwhile, five cases from previous phase are used and translated into computational readable format (from cases into formal expression) which used to evaluate the model. More explanation can be seen in chapter four.

3.7 Phase 6: Evaluation

A set of local and global dynamic properties were verified against the generated simulation traces which is provided in phase 3. In this study, two techniques have been used in order to verify the model, which are mathematical analysis (stability analysis) and automated verification analysis (Temporal Trace Language). Stability analysis aims to verify the equilipria points for the proposed model as indicators the model has been developed accordingly. On the other hand, temporal trace language is used to insure the correctness of the model in explaining possible cases existed in literature. More details and explanation can be seen in chapter four.

3.8 Summary

This chapter presents the research methodology stages which involved six phases; identification of local dynamic properties, formalization local properties, simulation, identification of non-local dynamic properties, formalization non local properties, and evaluation, and all of these phases have been achieved. Moreover, the outcome of the first phase was twenty four local property and all of these factors are highly contribute to the level of victims' stress. After that, these factors are formally presented by using differential equations to be in term of executable dynamic properties in order to implement simulation process. Also, five different cases were identified from past literature to be used in evaluation process and more discussion is made in upcoming chapter.

CHAPTER FOUR
SIMULATION RESULTS AND VERIFICATION

This chapter has shown the results on simulation traces and evaluation processes.

4.1 Simulation Results

As mentioned in chapter 3, for experimental issues and to give deep insight for psychologists, simulation traces was developed. Three cases of victims was simulated; namely, less vulnerable victims; moderately vulnerable victims, and finally, highly vulnerable victims.

Case #1: Less vulnerable Victims

In this case, victim has low level of stress when he/she affected by stressful event. In respect to this case, victim has good personality (positive personality) and high level of personal resources. Moreover, the quantity of social support and level of normal experiences are big enough to play an essential role to increase victim's resilience. Table 4.1 explains the input values used to simulate case #1.

Table 4.1 Values of Case #1

Factors	Given Values
Stressful event (Se)	1
Imminence of Harm (Ih)	0
Social support (Sc)	0.9
Positive Personality (Ps)	1
Experiences (Ep)	1
Perceive of Harm (Ph)	0
Normal experiences (Epnorm)	0.9
Personal Resources	1

After run the simulation code (matlab), the obtained result is showed in figure 4.1.

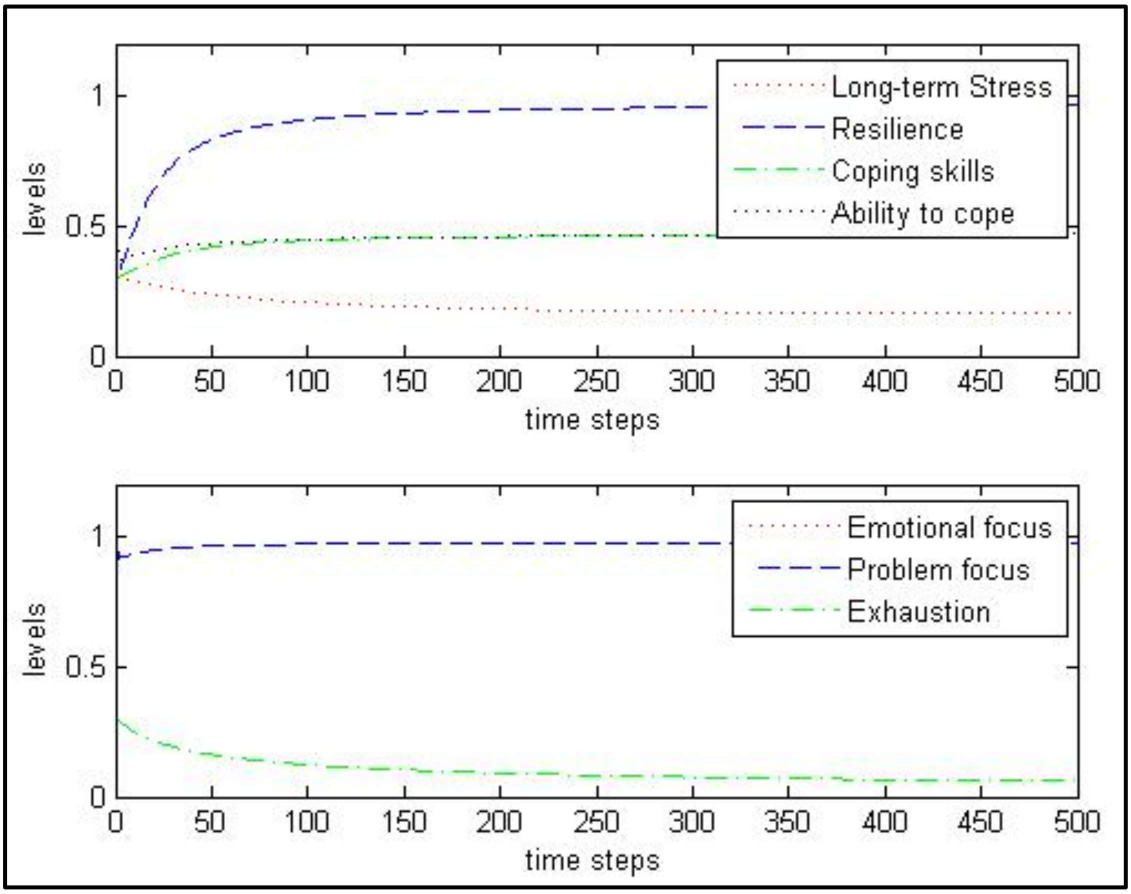

Figure 4.1: Simulation Result of Case #1

Based on figure 4.1, it can be seen that level of stress is decreased gradually when individuals are facing stressful event. Also, it showed that level of resilience is going high and problem focus coping has been used by individuals to get the problem solved as well as people are developed their coping skills. Moreover, emotional focus coping no longer used and exhaustion in coping is decreased.

Case#2: Moderately Vulnerable Victims

In this case, victim has moderate level of positive personality and social support is not much enough. Also, he/she has moderate level of personal resources to be used in facing stressful event. As well as, individuals are having moderate level of experiences to deal with the event. All of given values to simulate case#2 have showed in table 4.2.

Table 4.2: Values of Case #2

Factors	Given Values
Stressful event (Se)	1
Imminence of Harm (Ih)	0
Social support (Sc)	0.5
Positive Personality (Ps)	0.5
Experiences (Ep)	0.5
Perceive of Harm (Ph)	0
Normal experiences (Epnorm)	0.6
Personal Resources	0.4

Figure 4.2 explains the result that obtained from simulating case #2.

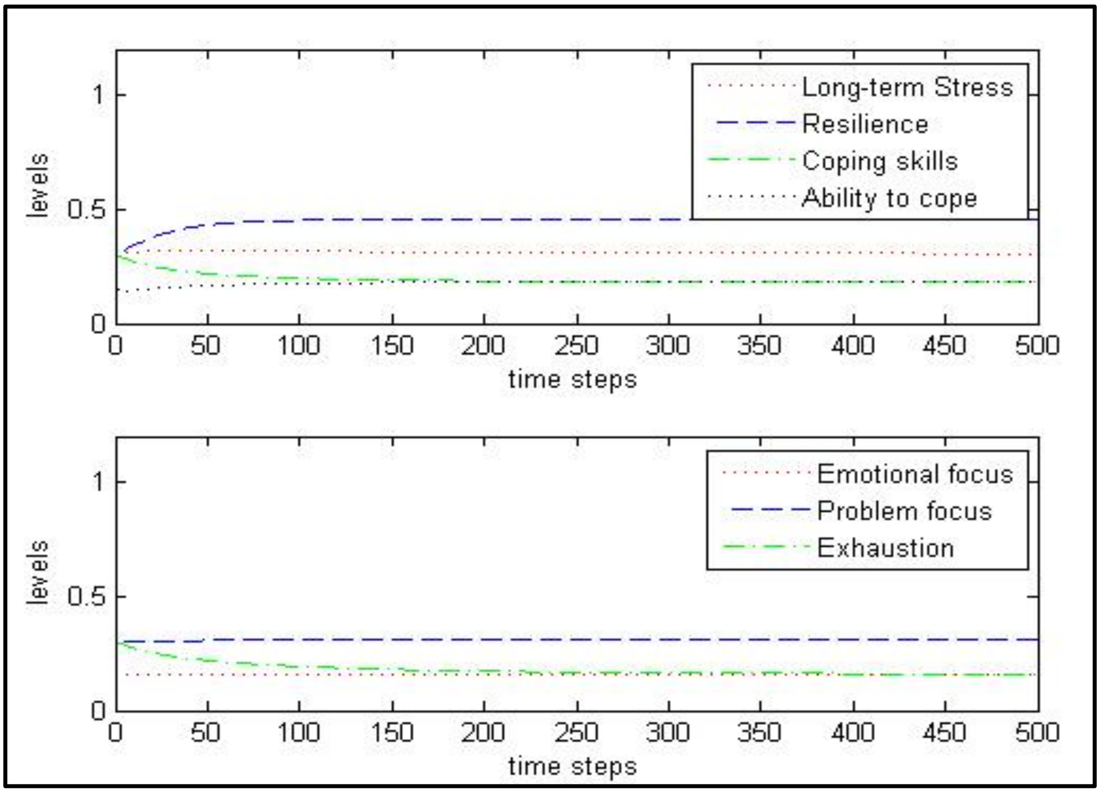

Figure 4.2: Simulation Result of Case #2

Based on figure 4.2, it can be seen clearly that all factors have moderate levels. In this case, individuals developed moderate level of stress. Resilience, coping skills, and ability to cope have moderate level over the time whereas exhaustion slightly decreased then settled at moderate level. Both of emotional focus and problem focus have used to deal with the situation.

Case#3: Highly Vulnerable Victims

In this case, individuals have high risks to develop high stress over the time when they encounter the stressful event. Negative personality and low level of personal resources are available, as well as, there is no social support provided. Also, individuals have not faced stressful event before (i.e. low level of experiences). All of these factors as indicators to develop high stress. Table 4.3 explains the input values used for case #3.

Table 4.3 Values of Case #3

Factors	Given Values
Stressful event (Se)	1
Imminence of Harm (Ih)	1
Social support (Sc)	0
Positive Personality (Ps)	0
Experiences (Ep)	0
Perceive of Harm (Ph)	1
Normal experiences (Epnorm)	0
Personal Resources	0

The obtained result of simulation trace is provided in figure 4.3 below.

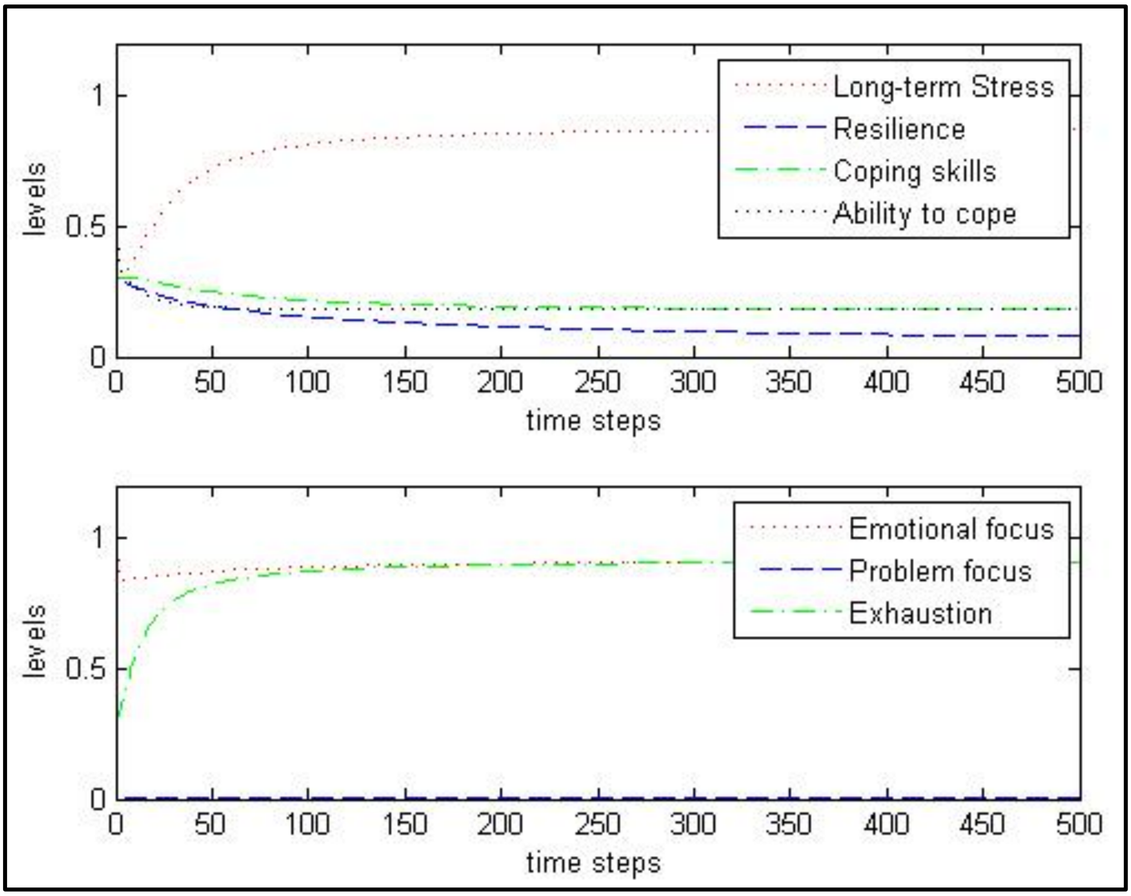

Figure 4.3: Simulation Result of Case #3

Based on figure 4.3, the level of stress is increased gradually with all availability of negative factors such as low level of experiences and negative personality as well as little social support has provided. In this case, individuals are using emotional focus coping rather than problem focus to face the stressful event and high level of exhaustion has initiated as a result of unsatisfactory outcomes.

4.2 Mathematical Verification

As aforementioned in 2.8.1, mathematical verification is a method to evaluate the computational model, moreover, for the proposed model; the equilibria can be done to assume constant values for all variables (also the ones that are used as inputs). Then in all of the equations the reference to time *t* can be left out, and in addition the differential equations can be simplified by cancelling, for example *Ls* $(t+\Delta t)$ against *Ls(t)*. One important assumption should be made; all exogenous variables are having a constant value. Assuming all parameters are non-zero, this leads to the following equations where an equilibrium state is characterized by:

$dLs(t)/dt = \zeta_{ls}.(1 - Ls).[Ss - Ls].Ls$ Eq.19

$dCs(t)/dt = \beta_{cs}.(1 - Cs).[Ac - Cs].Cs$ Eq.20

$dRs(t)/dt = \kappa_{rs}.(1 - Rs).[Hd - Rs].Rs$ Eq.21

$dEx(t) = \mu_{ex}.(1 - Ex).[Ef - Ex].Ex$ Eq.22

For equilibrium it has to hold that all of the derivatives are zero;

dLs(t)/dt=0, dCs(t)/dt=0, dRs(t)/dt=0, dEx(t)/dt=0

Assuming ζ_{ls}, β_{cs}, κ_{rs}, μ_{ex} are equal to 1, therefore, these are equivalent to;

$(Ss-Ls) \vee (Ls=0) \vee (Ls=1)$ Eq.23

$(Ac-Cs) \vee (Cs=0) \vee (Cs=1)$ Eq.24

$(Hd-Rs) \vee (Rs=0) \vee (Rs=1)$ Eq.25

$(Ef-Ex) \vee (Ex=0) \vee (Ex=1)$ Eq.26

Hence, a first conclusion can be derived where the equilibrium can only occur when Cs=1, or Cs=0, or Ac=Cs (refer to equation 24). By combining these three conditions, it can be re-written into a set of relationship in (A ∨ B ∨ C) ∧ (D ∨ E ∨ F) expression:

(Ss-Ls ∨ Ls=0 ∨ Ls=1) ∧ (Ac-Cs ∨ Cs=0 ∨ Cs=1) ∧ (Hd-Rs ∨ Rs=0 ∨ Rs=1)
∧ (Ef-Ex ∨ Ex=0 ∨ Ex=1) Eq.27

This expression can be elaborated using *law of distributivity* as (A ∧ D) ∨ (A ∧ E) ∨ (A ∧ F) ∨, …, ∨ (C ∧ F).

(Ss-Ls ∧ Ac-Cs ∧ Hd-Rs ∧ Ef-Ex) ∨ (Ss-Ls ∧ Cs=0 ∧ Rs=0 ∧ Ex=0) ∨, ..., ∨ (Ls=1∧ Cs=1 ∧ Rs=1∧ Ex=1) Eq.28

Eq.28 later provides possible combination equilibria points to be further analyzed. However, due to the large number of possible combinations, (in this case 3^4 =81 probabilities), it makes hard to provide a complete classification of equilibria. However, for some typical cases the analysis can be pursued further.

Case #1: Ls=1∧ Cs=1 ∧ Rs=1∧ Ex=1

For this case, by equation (4) its follow that,

$Ih = 0$

and hence by equation (17)

$Ss = \delta_{ss}. Se + (1 - \delta_{ss}). [1- Hd]$

Moreover, from (Eq.14) its follow,

$Ac = w_{ac1}. Pf + w_{ac2}. Ef - \mu_{ex}$

Finally, from (Eq.9) its follow,

$Ep = \lambda_{ep}. Ep_{norm} + (1- \lambda_{ep})$

Case #2: Cs=0

For this case, from the equation (4), its follow that the case is equivalent to:

$Ih = Ph$

and from (Eq.17) its follow that,

$Ss = \rho_{ss}.\ Se + (1 - \rho_{ss}).\ [\ Ex.\ (\ 1 - Hd)\ ]$

Case #3: Rs=1

In this case, from equation (9), it follows that the case is equivalent to:

$Ep = \lambda_{ep}.\ Ep_{\boldsymbol{norm}} + (\ 1 - \lambda_{ep})$

Case #4: Ex=1

For this case, from equation (14), it follows that this case is equivalent to:

$Ac = \mathrm{w}_{ac1}.\ Pf + \mathrm{w}_{ac2}.\ Ef - \mu_{ex}$

Moreover, from (Eq.17), its follow,

$Ss = \delta_{ss}.\ [Se.\ (1 - Cs)\ ] + (\ 1 - \delta_{ss}).\ [\ 1 - Hd]$

4.3 Automated Verification

Logical verification is a method to verify the correctness of the model and it considers as an internal validation as explained in 2.8.2, moreover, five cases were found from literature review and all these cases are verified as below.

1. In a stressful event, when an individual has experienced the event before(high level of experiences), will increase the level of resilience to encounter upcoming event (Seery, 2011).

VP1 ≡ ∀γ:TRACE,t1,t2:TIME,D1,D2,R1,R2:REAL, ∀X:INDIVIDUAL
[state(γ, t1)|= experienced_level(X, D1) &
state(γ, t2)|= experienced_level(X, D2) &
state(γ, t1)|= resilience_level(X,R1) &
state(γ, t2)|= resilience_level(X,R2) &
t' > t & D2 ≥ D1] ⇒ R2 ≥ R1

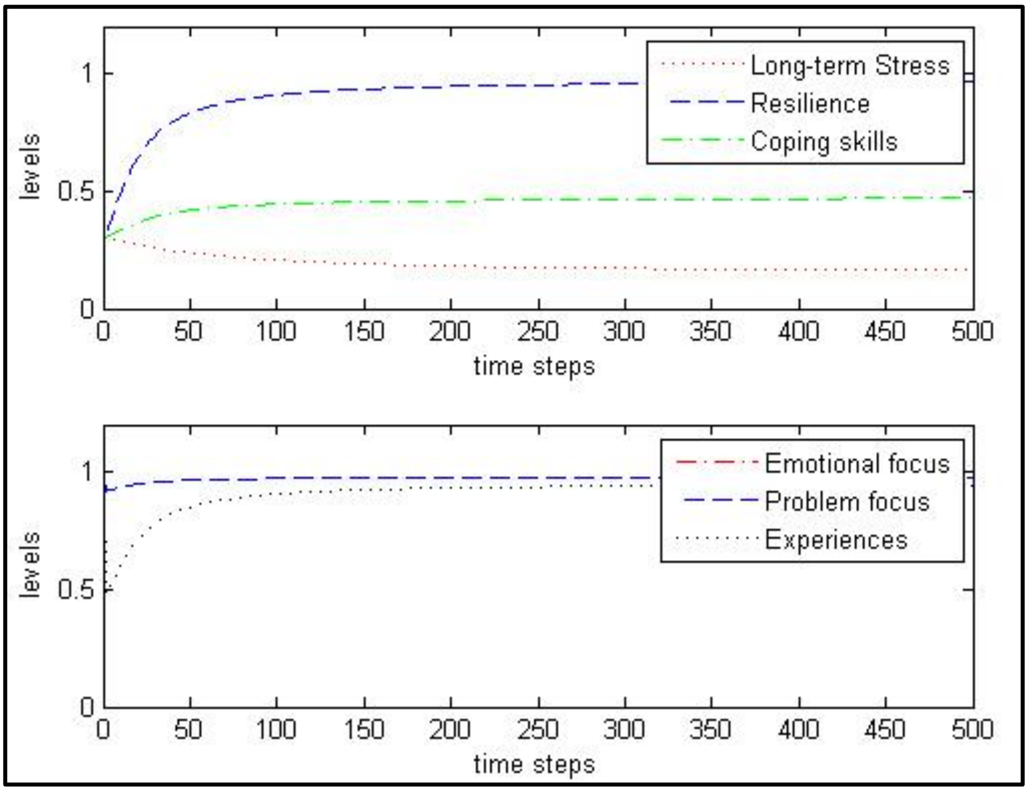

Figure 4.4: Simulation Result of Experiences and Resilience level

2. Pre-stressful event social support is playing an essential role to decrease both exposure to natural disasters and the negative psychological effects of natural disaster exposure (Lowe, Chan, & Rhodes, 2010).

VP2≡∀γ: TRACE, ∀R1, R2, L1, L2: REAL, t1,t2:TIME, ∀X:INDIVIDUAL
[state(γ,t1)|= social_support(X, R1) &
state(γ,t2)|= social_support(X, R2) &
state(γ,t1)|= high_level_stress(X, L1) &
state(γ,t2)|= high_level_stress(X, L2) &
t2=t1+d & R2 ≥R1] ⇒ L2 ≤ L1

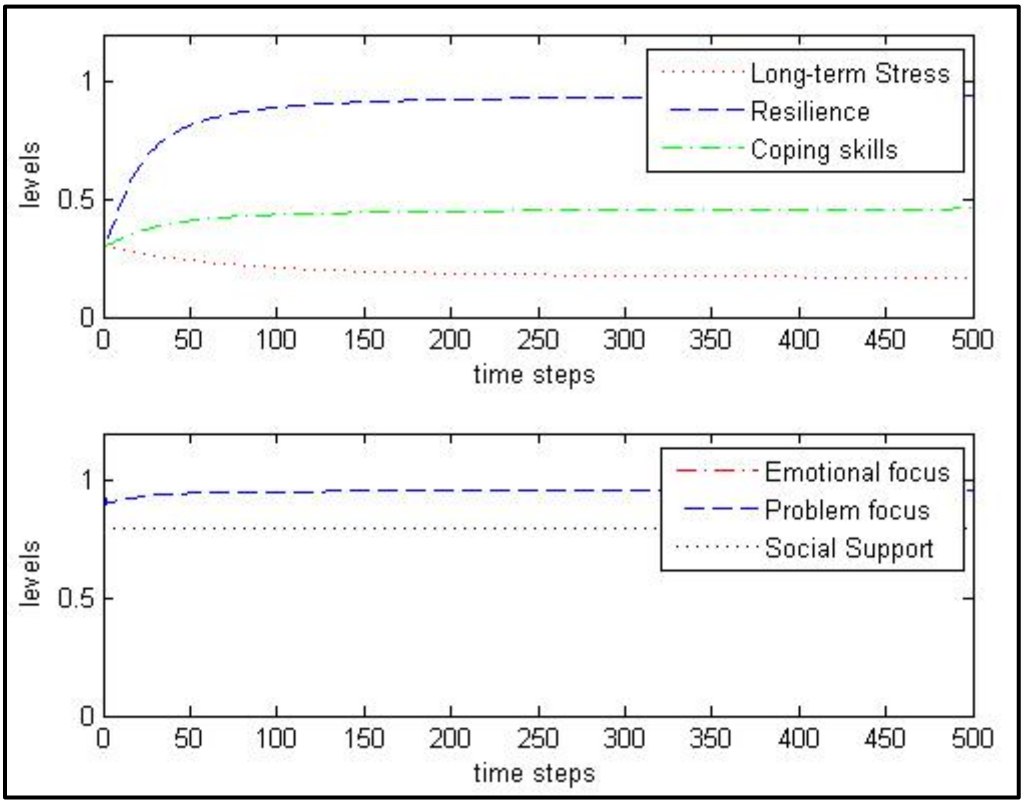

Figure 4.5: Simulation Result of Social support and Level of stress

3. The quantity of resources loss in a stressful event will increase the level of psychological effects such as stress (Freedy, Shaw, Jarrell, & Masters, 1992).

VP3≡∀γ: TRACE, ∀R1, R2, L1, L2: REAL, t1,t2:TIME, ∀X:INDIVIDUAL [state(γ,t1)|= personal_resources(X, R1) &
state(γ,t2)|= personal_resources(X, R2) &
state(γ,t1)|= high_level_stress(X, L1) &
state(γ,t2)|= high_level_stress(X, L2) &
t2=t1+d & R2 ≤ R1] ⇒ L1 ≤ L2

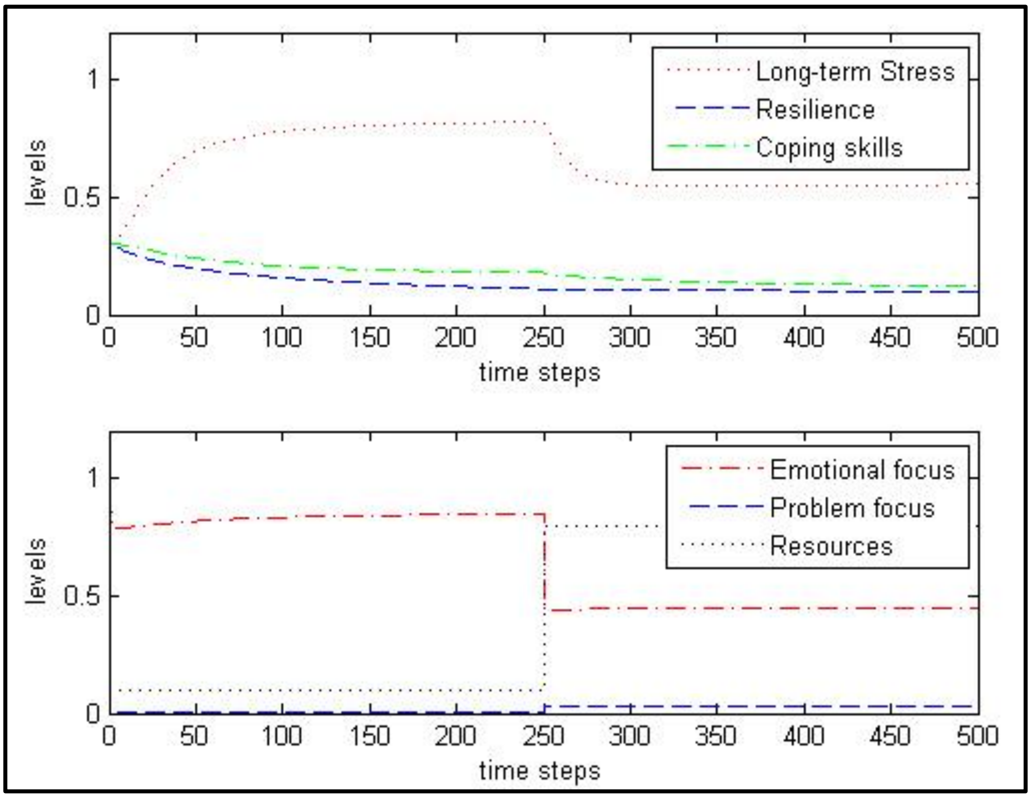

Figure 4.6: Simulation Result of Personal Resources and Level of stress

4. High level of individual's resilience will decrease stress level while facing a stressful event(Tung, Ning, & Kris, 2014).

VP4 ≡ ∀γ:TRACE, ∀t1, t2:TIME, ∀M1, M2, d:REAL, ∀X:INDIVIDUAL [state(γ, t1)|= resilience_level(X, M1) &
state(γ, t2)|= long_term_stress(X, M2) &
M1 ≥ 0.8 & t2= t1+d] ⇒ M2 ≤ 0.4

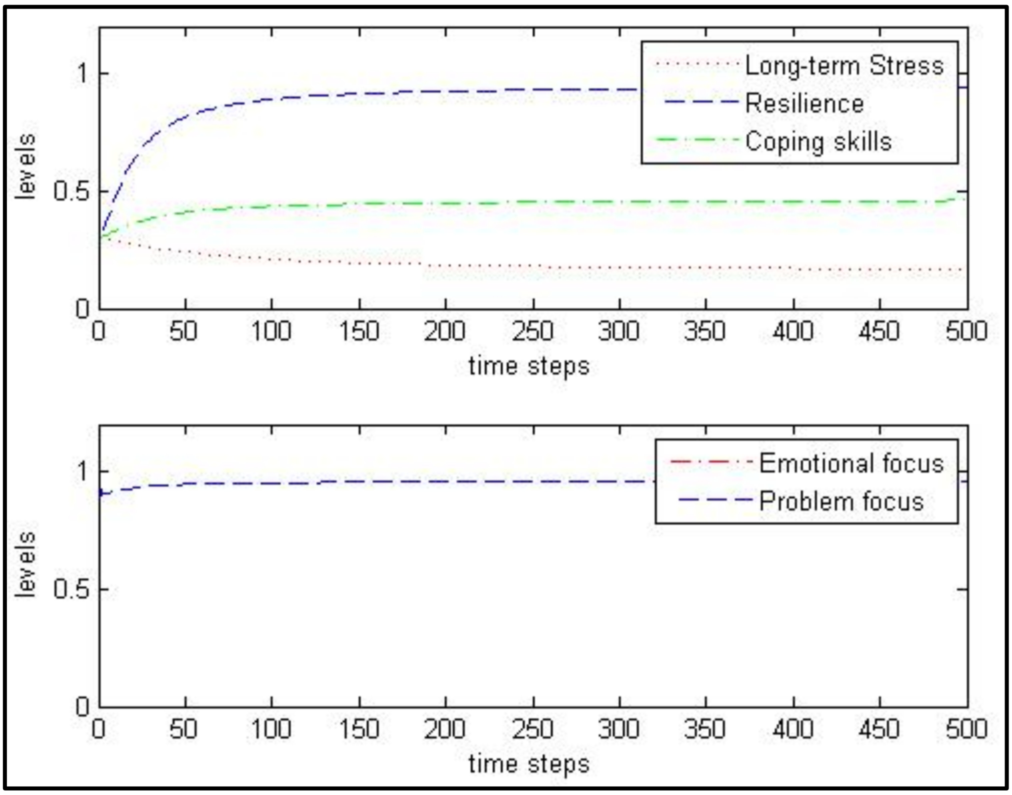

Figure 4.7: Simulation Result of Resilience and Long Term Stress

5. Problem-focused coping will help to reduce high level of stress monotonically during stressful event (Dimiceli, Steinhardt, & Smith, 2010).

VP5≡∀γ: TRACE, ∀R1, R2, L1, L2: REAL, t1,t2:TIME, ∀X:INDIVIDUAL
[state(γ,t1)|= problem_focus_coping(X, R1) &
state(γ,t2)|= problem_focus_coping(X, R2) &
state(γ,t1)|= high_level_stress(X, L1) &
state(γ,t2)|= high_level_stress(X, L2) &
tb ≤ t1 ≤ te & tb ≤ t2 ≤ te & t1< t2 & R2 ≥ R1] ⇒ L2 ≤ L1

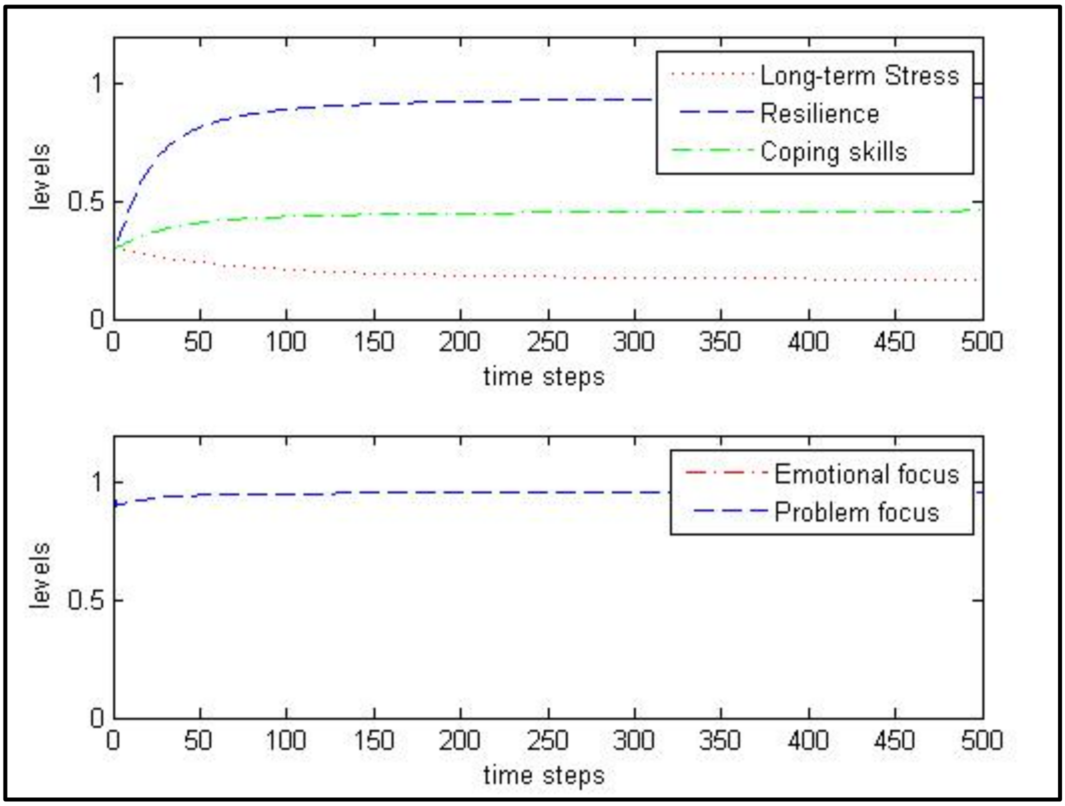

Figure 4.8: Simulation Result of Problem Focused and Level of Stress

4.4 Summary

This chapter illustrated the outcome of simulation and verification processes. It showed three different scenarios of simulation which are highly vulnerable victims, moderately vulnerable victims, and less vulnerable victims. Moreover, evaluation techniques (mathematical analysis and automated verification) were provided and achieved.

CHAPTER FIVE
CONCLUSION

This study has demonstrated important issues related to the level of victims' stress during natural disaster, and according to what have achieved, this chapter concludes the outcomes of this study and presents limitation and future work.

5.1 Conclusion

In this study, the terms of natural disaster (especially flooding in Malaysia) and psychological consequences (stress) were explained carefully. As stated in Chapter One, there three main objectives were formulated; 1) identifying psychological attributes and relationships related to victims' stress level during natural disaster, 2) developing a formal model related to the identified factors, and finally, 3) evaluation of the proposed model. Based on the work in Chapter Three and the results provided in Chapter Four, those objectives have been achieved.

Based on theories and models as well as empirical studies which answered the question "why people develop different level of stress when they encounter stressful event, twenty four local dynamic attributes related to victims' stress level during natural disaster" were identified. These are stressful event, imminence of harm, positive personality, social support, experiences, personal resources, challenge, threat, harm, control, commitment, resilience, hardiness, acceptance, holdback, emotional focus, problem focus, ability to cope, exhaustion in coping, coping skills, short term stress, and long term stress. Moreover, individuals' appraisal is taking an essential role to determine the level of individual's stress as well as a set of personality attributes and other external factor such as the quantity of social support they receive. Based on that, first objective has been achieved.

Second objective has been achieved through the development of a formal model by formalizing all identified factors from previous objective. Then, this model has been simulated using Matlab. Later, this model was tested with three different cases; highly vulnerable victims, moderately vulnerable victims, and less vulnerable victims, to represent specific circumstances such as different personality and environment settings.

Third objective which involves evaluation processes has been achieved. Moreover, two evaluation techniques were used which are mathematical verification (stability analysis), and automated verification. In case of mathematical verification, four different equilibria points were used to show the stability as mentioned in Section 4.2. In addition, five different non-local dynamics properties have identified from past literature and each non-local property has been formulated using Temporal Trace Language (TTL) to be used for an automated verification as illustrated in Section 4.3.

5.2 Limitation

This study presented a formal model which is based on psychological and cognitive theoretical knowledge and yet to involve any neurology (or neuro-psychology) aspects. Moreover, the use of this formal model is limited to capture solely the dynamic of victims' stress, while the dynamics of volunteers' stress needs to be studied to develop a model which involves all people who are facing natural disasters such as floods.

5.2 Future Work

There are various areas where further research is needed. Though the mathematical and automated analyses described in Chapter Four have been successfully performed to guarantee its internal validity, this does not guarantee that this model can be directly applicable to the real world. Therefore, the future work should include the implementation of this model in a real robot or virtual avatar in order to ensure real world validation could be achieved. Thus, it will achieve the ultimate mission of this work by providing such support for victims during natural disaster. Furthermore, this model could be used as a training environment tool to understand internal and external processes of flood victims' stress during the event of natural disaster.

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