Innovative Vector Control Methods for Improving Dengue Control in Papua New Guinea

A dissertation submitted to Auckland University of Technology in fulfilment of the requirements for the degree of Master of Public Health

March, 2018

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Dedication

Before I dedicate this achievement to some very special people in life whose contribution has made it possible to reach this level of education, I thank God for the wisdom, strength and protection. I dedicate this achievement to my ageing mom Siri and dad Agovaneta Haguna, who are simple village farmers in a rural village in Papua New Guinea (PNG) who sacrificed the little they earned from selling coffee beans to keep me going until I finished college as a starting point to my career. This dedication is also extended to my elder sister Ago and her husband Jim for their support throughout my primary, secondary and tertiary education, and to my daughters Eli, Utu and Sofira for their patience back home in PNG fending for themselves during the three years I have been studying in New Zealand.

A very special mention to my church members in New Zealand starting with Pastor David Pearson and family including James and James, Kelly Rouse and family including the four lovely kids, Steve Rowe and family, Steve Curby and family, with Joji and Hannah Ramasima for their invaluable support, love, care and encouragement including taking me to new places in New Zealand. God bless all.

Acknowledgements

There are some great and wonderful people whom I would like to acknowledge and thank them for taking their precious time to make sure I complete my Dissertation within the scheduled time. My first and very special appreciation and acknowledgement goes to my immediate thesis supervisor and Lecturer in Public Health, Kate Kersey and Post Graduate Program Leader, Amanda B. Lees for their very useful, relevant and great feed-backs to keep me on track right to the last day of submission.

My other special acknowledgement is forwarded to my sponsors, New Zealand AID (NZAID) Programme and National Department of Health (NDOH), Government of PNG for recognising my potential and giving me the opportunity to undertake the Master of Public Health program. On the same note, my very special thanks to Sacha Pointon (Senior Scholarships Officer) and Margret Leniston (Administrator), Ruth and Prema (Accounts Officers)at AUT, New Zealand, Saidi Lani, Principal of Highlands Regional College of Nursing, PNG) and Julian Aihi at the National Department of Health (NDOH) for providing the necessary support during my study period from February, 2015 to the completion of my program in March, 2018.

Further acknowledgement and appreciation is forwarded to Dr David Parker, Senior Student Advisor for Post Graduate Studies at AUT, whose professional academic guidance had a positive impact on the outcomes my assessments including the final dissertation. I also would like to acknowledge both Dr. Jonah Tisam and Dr. Chris Naughton for their professionalism in editing and proof-reading my assessments including the final dissertation. Finally, a special mention to my two course mates, McDonald from Malawi and Angelita from East Timor for their moral support and prayers.

Abstract

Background: Dengue Fever (DF) is a common vector-borne disease of the tropical and sub-tropical world where more than 50% of global population lives, and recognised by the World Health Organization (WHO) as a notifiable public health disease transmitted by the *Aedes* mosquito. With the changing climatic temperatures, increased international travel and trade, and poor disposal of water holding objects in home environments, DF is rapidly expanding to new geographical areas once virgin to the *Aedes* vector. DF is also an opportunistic infection in persons with low immunity including young children, pregnant women, and adults living with an on-going illness. DF is a significant public health issue in Papua New Guinea (PNG). The **aim** of study is to review literature on: (1) the effectiveness of the PNG Dengue Control Program (DCP) and; (2) the effectiveness of Innovative Vector Control Methods (IVCMs) implemented or piloted in other dengue-endemic countries and their feasibility to a PNG context. The two **research questions** decided for this study to answer are: *(1) "In light of the socio-economic, cultural and environmental determinants impacting on DF control in PNG, how successful has the PNG DCP been?" (2) "What IVCMs that were either trialled, piloted or implemented in other dengue-endemic countries, may be applicable in a PNG context to improve DF control and prevention?"* **Methodology:** Given the significance of this study, a "Critical Literature Review" (CLR) was considered the most relevant approach for this study. The **search strategy** used for an online AUT Library search on 17/09/17 to identify 6182 references included the use of key databases as search machines were Pub-Med, Google Scholar and Med-Line. **Key search terms** used were, but not limited to; "dengue fever," "dengue fever control," "PNG dengue control," "dengue prevention," "climate change and socio-economic, cultural and environmental factors," and "innovative vector control methods." Through an **inclusion criterion,** 98% (6078/6182) irrelevant articles or those written in a non-English language or published before 2000 were eliminated followed by a further elimination of 54 systemic reviews, non-scholarly state documents and agency reports outside of PNG. Of the retained 50 articles, 20% (10/50) were directly to PNG DCP, while IVCM-related articles constituted 80% (40/50). **Data analysis:** Going beyond routine descriptive methods of data analysis, a thematic analysis of findings from both reviews using sub-themes and supplementary questions to draw conclusions. **Results of review 1: The effectiveness of the PNG DCP:** Burden of DF in PNG remains unknown due to lack of skilled staff, poor diagnostic facilities and an absence of a DF surveillance system. While young age is a risk factor for DF infection in PNG, the impact of socio-economic, environmental and cultural influences in DF transmission and its control was significant with little or no effort in community mobilization, empowerment and participation. **Results of review 2: The effectiveness and feasibility of IVCMs in a PNG context.** The non-insecticide-based IVCMs including the Health Belief Model (HBM) for community DF education and the inter-sectoral participatory methods are likely to be sustainable under PNG socio-economic, cultural and health system contexts. **Conclusions:** Despite DF been a very important public health disease expanding rapidly to new areas, little effort has been done to control its transmission in PNG with the current PNG DCP achieving little success. The impact of socio-economic, environmental and cultural factors including globalization, trade and climate change on DF transmission and its control was significant. **Recommendations:** HBM-based DF education and youth and women group participation as examples of both participatory and inter-sectoral IVCMs are considered immediate to intermediate intervention measures for promoting social mobilization, empowerment and participation. These strategies are particularly important for communities to sustain environmental hygiene, proper waste disposal and sanitation including safe water supply. In comparison, insecticide-based IVCMs including larviciding, using repurposed insecticides, can be considered long-term strategies for comprehensive destruction of mosquito populations from the environment. While an effective DF surveillance system remains a top priority in PNG for evidence-based DF control, participatory action research (PAR) is necessary to advocate for social justice to improve and empower deprived under-privileged communities to have equal access to information on DF control.

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Appendices

Abbreviations

AD…………………………………………………….………. After Death (of Christ)

AUT…………………………………...….… Auckland university of Technology

APSED……………………......…. Asia-Pacific Strategy for Emerging Diseases

CPHL……………………………….………… Central Public Health Laboratory

CDC…………………………..…………………. Centre of Disease Control

CLR………………………………………..………………Critical Literature Review

DCP…………………………………………….………….... Dengue Control Program

DENV 1, 2, 3, or 4………………………….... Dengue viral serotypes from 1-4

DF……………………………………………………...…………. Dengue fever

DHF………………………………………….….... Dengue Haemorrhagic Fever

DSS ………………………………......….….…. Dengue Shock Syndrome

ID…………………………...………………………….……. Identification

IEC………………………....……Information, Education & Communication

EPA……………………………………...…. Environmental Protection Authority

GDS…………………………………….…………… Global Dengue Strategy

IHRs……………...........................………… International Health Regulations

IMR………………………………...………… Institute of Medical Research

IMS-Dengue……………….….… Integrated Management Strategy for Dengue

IVCC ……………………..………..…. Innovative Vector Control Consortium

HIV ……………………….………..……. Human-Immune Deficiency Syndrome

LA ……………………………………………………………..…….Latin America

LNG …………………………...……..……………….…. Liquidified Natural Gas

MPH …………………….…………………….…...……. Master of Public Health

NCD …………………………………………………. National Capital District

NCDC ……………………………………… National Capital District Commission

NDOH ……………………………………………. National Department of Health

NHIS ………………………………………… National Health Information System

NSO …………………………………………………. National Statistics Office

NZ ………………………………………………………………. New Zealand

PAHO ………………………………………. Pan American Health Organization

PHS ………………………………………………………. Public Health System

PNG ……………………………………………………….. Papua New Guinea

PPP ……………………………………………………...Public-Private-Partnerships

SEAR ……………………………………………….. South-East Asia Region

TB ……………………………………………………………… Tuberculosis

UNDP ………………………………….. United Nations Development Program

USA ………………………………………………. United States of America

WHO ……………………………………………World Health Organization

WWII ……………………………………………………………… World War Two

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Attestation of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed ____________________________ Date_______________________

Chapter One: Background

1.1 Introduction

Dengue fever (DF) is one of the fastest emerging vector-borne diseases of the tropics and sub-tropical regions with more than 50% of the world's population exposed to risk of DF infection (Finkelman, 2015; Lashley & Durham, 2007) (Figure 1). Bhatt et al., 2013) estimated that, following the World Health Organization (WHO, 2009) yearly global DF estimates, DF has now almost tripled to more than 390 million infections (95% CI=284-528). This alarming public health problem has prompted Visser, Narayanan and Campbell (2012) and WHO (2012) to predict massive expansion of the DF vector (*Aedes* mosquito) over vast and new geographical areas which may become difficult to control. See Figure {1}.

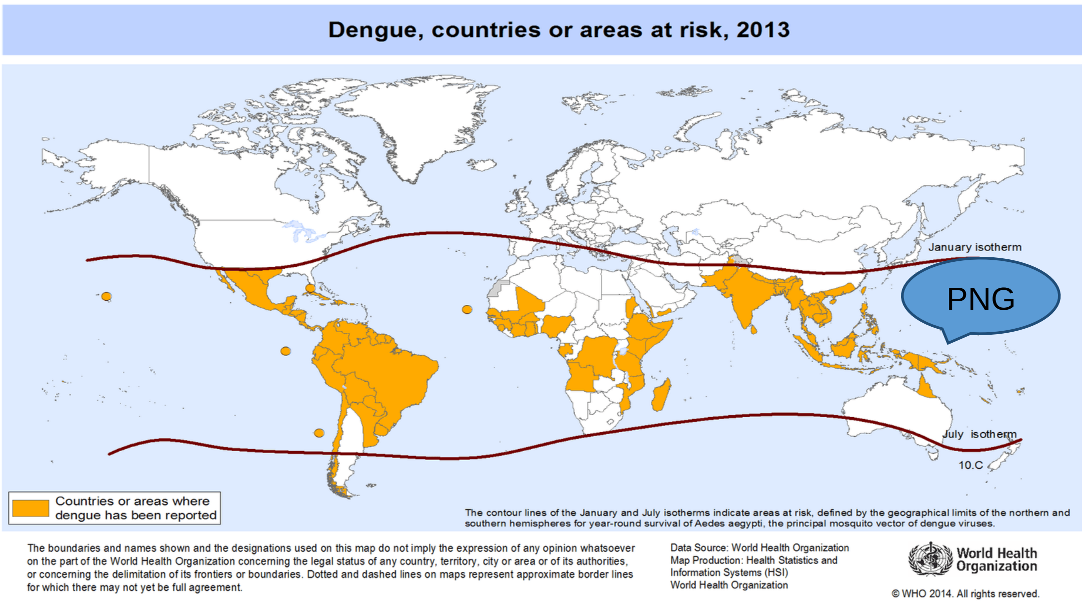


Figure 1. The 2013 Global Dengue Map showing dengue risk countries including PNG. ***Source:*** WHO Map production (2014). Health Statistics and Information Systems: http://apps.who.int/iris/bitstream/10665/111008/1/WHO_DCO_WHD_2014.

DF is primarily caused by one of the four *Aedes* mosquito serotypes which only produce life-long immunity to itself rather than a cross-protection against other serotypes (WHO, 2011b). This may not only imply an absence or little protection against a second episode from a different serotype (Kularatne, 2015), but may also lead to more severe forms such as Dengue Haemorrhagic Fever (DHF) or Dengue Shock Syndrome (DSS) particularly in children and older persons whose immunity has been suppressed by existing health conditions (Bhatt et al., 2013). Given the fatality rate of DHF and DSS due to serious complications involving multiple of organs (Whitethorn & Farrar, 2010), it is important that education on DF prevention as priority number one is imparted to communities and families living in DF-risk areas.

According to both Garcia-Rejon et al. (2016) and Selvan and Jebanesan (2016), the *Aedes* mosquito becomes very productive inbreeding and transmitting DF only when there is a conducive home environment. As Garcia-Rejon et al. (2016) explained, a man-made environment conducive for productive mosquito breeding and transmitting of DF may feature an uncontrolled disposal of tins, bottles, containers or old tyres left lying around homes, especially in urban settlements (Figure 2). Such scenarios may demonstrate not only community's lack of DF knowledge; but, may also indicate a lack of community empowerment and social mobilization necessary for home-based DF prevention and control (Basurko, Carles, Youssef &Guindi, 2009).

DF pathogenesis, its potential routes for transmission including major risk factors have been established and widely understood (WHO, 2009a); however, an accurate estimate of the total global burden of DF remains unknown (Brady et al., 2012). In addition, public health attention and resource allocation have shifted from routine vector control measures to the initiation and development of anti-viral drugs and DF vaccine with little or no significant success (Nwaka& Ridley, 2003; Bhatt et al., 2013). Such public health policy changes on the control of vector-borne diseases have been implicated to give rise in the trend of widespread re-emergence and re-surfacing of these diseases (Hemingway et al., 2006; Harrus & Baneth, 2005).

A man-made home environment conducive for mosquito breeding is one risk factor in the transmission of DF from within homes

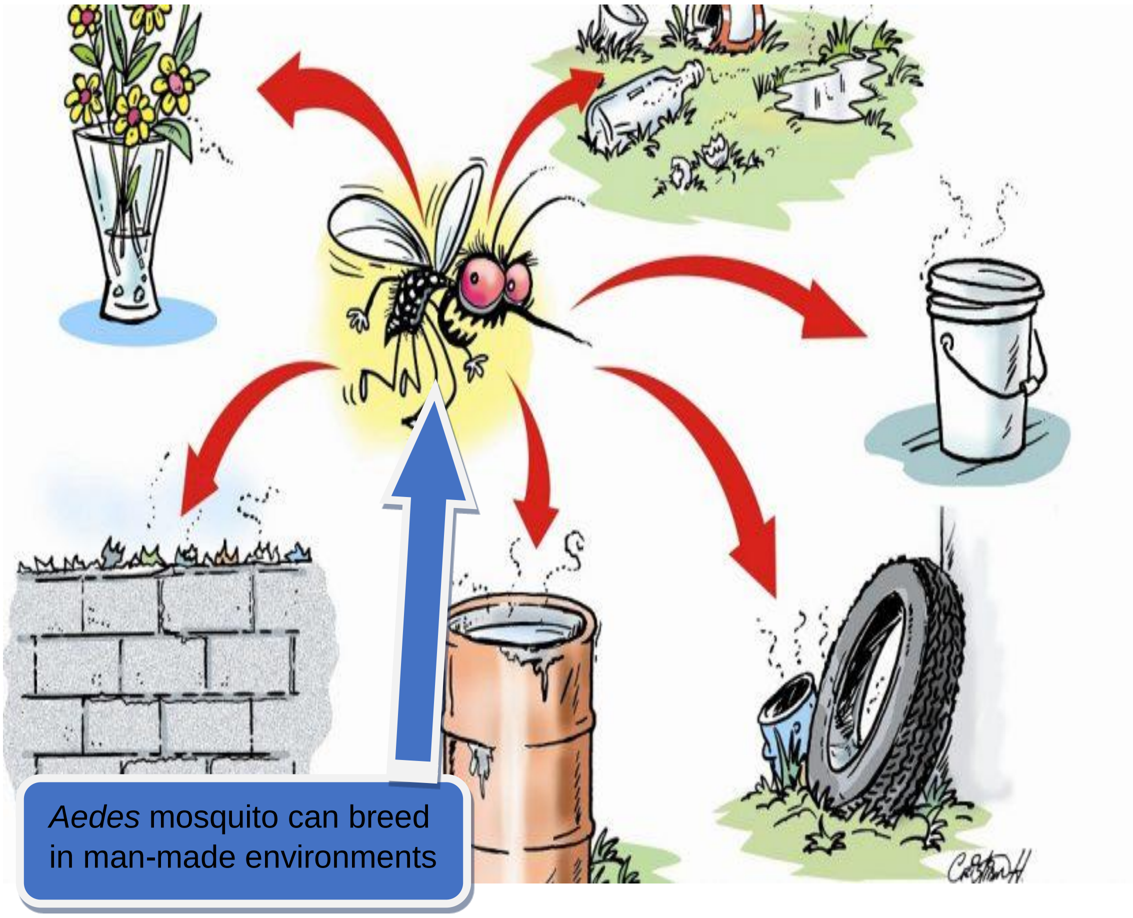


Figure 2. An illustration of a home environment filled with productive *Aedes* mosquito (DF vector) breeding sites. **Source:** Pakistani Ministry of Health from https://www.pakistantoday.com.pk/2017/09/27/ meeting-held-to-review-preventive-measures-against-dengue/

1.1.1 Clinical definition and classification

Dengue Fever is a deliberating viral disease characterised by sudden onset of fever, general body malaise and an appearance of clear skin haematoma spots (Deen et al., 2006; Murray, Quam& Wilder-Smith, 2013). Because of its intense pains in the joints, muscles and bones of the cranial cavity and eye socket areas, DF is commonly termed as a “break bone disease”

(Whitethorn & Farrar, 2010). Although DF transmission is not limited to a certain age or sex group, the most severe cases such as the Dengue Haemorrhagic Fever (HDF) and Dengue Syndromic Shock (DSS) are being highly reported among the younger age group (WHO, 2007).

A special clinical staging criterion is used for classifying DF infection based on its etiological and pathological processes that includes: (1) febrile stage, (2) critical stage, and (3) convalescent stage (WHO, 2009b; Cui et al., 2016) (Appendix C, page 111). Although the symptoms in the febrile phase of the disease can be mistaken for chikungunya and zika viruses, a sudden onset of high grade fever, general body weakness and dehydration lasting two to seven days provide clues for both clinical and laboratory investigations (Samtani Bhagia, 2015). Most febrile phase cases recover, although a lesser, but significant number of cases progress in to the critical phase characterised by a positive tourniquet test (Bhatt et al., 2013). A positive tourniquet test for DF is demonstrated by a clear fine line of blood spots across the arm after five minutes of constrictive band application (Feder Jr, Plucinski& Hoss, 2016).

For those few cases that progress from the febrile phase to the critical phase, there is evidence of plasma leakage, bleeding, shock and organ impairment over a period of three to seven days (Whitethorn & Farrar, 2010; Bhatt et al., 2013). Although it is unclear if some febrile cases advanced straight into the DSS phase (Bhatt et al., 2013), more than 50% of all critical cases progress to the convalescent phase characterised by involuntary bleeding from body orifices such as nose, gums, anus and vagina of child bearing women (Bhatt et al., 2013). When the convalescent phase is fully established, most of the symptoms in the critical phase become exaggerated, leading to the collapse of the cardio-vascular system with cold clammy skin, weakened, but rapid pulmonary pulse, lowered diastolic blood pressure and significant reduction in the volume of urine output (WHO, 2013a; Whitethorn & Farrar, 2010).

Clinical practitioners continue to face challenges in their clinical judgements in differentiating between the three phases of DF especially, between the critical and convalescent phases (Bhatt et al., 2013). The question surrounding the clinical separation between the three phases in the pathophysiological process remain an issue (Kularatne, 2015), with additional challenges in the confidence of clinicians to determine an appropriate method of intervention. Hence, this clinical scenario presents a challenging disease continuum in which critical cases become the centre of concern whether it improves or progresses to the convalescent phase while the febrile phase follows an uncomfortable but, relatively self-limiting, benign disease process.

For clinical intervention, Teixeira et al. (2002) had previously viewed DF as a complex disease presenting varying challenges not only in terms of clinical response, but also with the lack of preventive and control measures. Although the WHO DF case management protocols have been made available, many of the low-middle income DF reporting countries continue to lack diagnostic facilities which incapacitate them to fully utilise these strategies (2009b). In addition, the lack of priority given to all aspects of public health intervention programs including clinical, epidemiological and the sustaining of community-based vector control measures has given rise to further challenges.

1.1.2 Risk factors

Genetic-based disease transmission along family lines is an important factor to be considered when thinking about risk factors in both transmission of DF and its preventive measures (Pearce, Foliaki, Sporle & Cummingham, 2004). However, Reiheld (2008) reiterated that this route of transmission has been weakened to the extent that it has become rare with time as gradual improvements in the health practices have impacted on the lifestyles of individuals and families across different countries. Such thinking has led to an increasing literature on other key risk factors such as an unhealthy environment, poverty and a weakened body immune system due to other chronic health problems including TB, HIV or malnutrition (WHO, 2009a).

Pruss-Ustun (2016) linked DF transmission to human-based socio-economic and cultural practices influencing proliferation of *Aedes* mosquito population, breeding and disease transmission. In addition, individuals especially young children and adults living with existing medical problems such as tuberculosis (TB), Human Immune-Deficiency Virus (HIV) or malnutrition were most likely to at risk given weakened body immunity levels (Whitethorn & Farrar, 2010). Hence, DF transmission is also an opportunistic infection for such vulnerable children, pregnant mothers or sick adults living in DF-risk areas (Bhatt et al., 2013; Guzman et al., 2012; Tan et al., 2008).

Studies have established strong correlations have been established between change in climatic temperatures, conducive environmental (see Figure 2), and influences from socio-economic and cultural factors and DF transmission (Murray et al., 2013; Bi et al., 2001; Visser et al., 2011). Murray et al. (2013). WHO (2009b) also explained that DF transmission is also influenced by poor public health policies and infrastructures (WHO, 2009b). Such scenarios call for policy makers and implementers to make informed decisions in the planning and implementation of response efforts that target both DF pathogenicity (Simmons, Farrar, van Vinh Chau & Wills, 2012; Bhatt et al, 2013) and to reduce geographical-based endemicity (Bi et al., 2001; Visser et al., 2011; Murray et al., 2013).

In addition, Ferreira (2012) identified demographic changes such as uncontrolled population growth, rural/urban drift, economic trends in tropical countries and patterns of land use as obvious risk factors for DF transmission. A rapid increase in travel and international trade featured by the shipment of large volumes of cargo on ships makes the spread of DF vectors and pathogens across different regions more convenient (Wilson, 2007). As Basurko et at. (2009) has stated, DF will continue to threaten health and well-being of populations living in DF-risk geographical zones if drastic DF control measures including community mobilization and empowerment are not taken.

1.1.3 Historical perspective

DF has been present for centuries (Murray et al., 2013) with its first clinical characteristics recorded in a Chinese Medical Encyclopaedia in 992 AD (Gubler, 2006). However, its history of discovery published in the Chin Dynasty can be traced back to the earlier years between 265 and 420 AD, where it was first referred to as “poison water” associated with flying insects. The early occurrences of epidemics were only reported 600 years when its clinical manifestations were discovered in the West Indies in 1635 and in Central America in 1699 (Gubler, 2002; 2014).

Much later DF became a major public health concern in the United States of America (USA) with occurrences of two major epidemics; one in 1780 in Philadelphia and one in 1945 in New Orleans (Wilder-Smith & Gubbler, 2008). Throughout the post-World War 2 (WWII) period leading up to the 21st century, DF has become a public health priority in many parts of the world, which significantly increased people's awareness of the disease. Severe forms of DF including DHF and DSS were first discovered in the Philippines and Thailand in the 1950s which attracted the designing of appropriate clinical and preventive measures (WHO, 2011a; Gubler, 2006).

The viral aetiological processes and transmission of DF by mosquitoes was finally determined in the 20th century with counteractive measures taken to control its transmission (WHO, 2011b). A global brief report by WHO (2014) indicated an increase in the prevalence and circulation of female *Aedes aegypti* mosquito, where they breed in man-made containers and transmitting DF in many urban areas of Latin America (LA). This correlation in DF transmission and expansion was attributed to the transportation and expansion of the *Aedes albopictus* mosquito from Asia to LA via used tyres in cargo ships transporting trading goods (Wilder-Smith & Gubler, 2008).

1.1.4 Past to Recent Global DF Control Measures

The term "dengue control" may refer to primary DF control measures as statutory sanctioned public health orientated actions aimed at preventing further DF transmission in the community (Gubler, 2014). Some fine examples may include, but not limited to, epidemiological surveillance, destruction of vector breeding sites using chemical-based and non-chemical-based strategies, and mass public screening during epidemics. Although clinical effort is a key component in DF intervention, programs to reduce impact of the disease (Constenla et al., 2015), such as the promotion and sustaining of primary DF prevention at the community level, remain a priority.

Comparatively, “dengue prevention” according to Tana, Umniyati, Petzold, Kroeger and Sommerfeld (2012), is a process in which protection against DF is achieved for populations exposed to risk of DF transmission. As highlighted by Parks and Lloyd (2004), this term fits into a practical context; hence, avoidance of DF transmission can only be achieved through social mobilization, advocacy and empowerment of community membersto take ownership of proper disposal of organic and non-organic waste and methods for ridding mosquito breeding grounds (Parks & Lloyd, 2004; Winch et al. (2002). Such strategies can become potential tools to sustain community-based DF prevention strategies, especially when members become role models and agents for change in behaviour pertaining to home-based vector control (Tana et al., 2012).

Given the trend of climate change, international travel and trade, DF has become one of the most hypothesised vector-borne diseases likely to be sustained and expand over vast horizons (Murray et al., 2013; Lashley & Durham, 2007). DF is not only viewed as a complex disease as stated in its clinical manifestations, but it is also difficult to control given the non-availability of anti-viral drugs or DF vaccine (Guzman et al., 2010; Guy et al., 2011; Wilder-Smith, Ooi, Vasudevan & Gubler, 2010). As an international body responsible for better health and well-being of the global population, the WHO has taken the responsibility in developing better standard models since 2000 for improving DF control at global, regional and country levels (2011a).

The first model for improving both public health practice and policy development for DF control was the 2000 strategy for strengthening DF prevention (WHO, 2000). This strategy acted as a benchmark for initiating varying DF control programs in an attempt to halt the wide-spread emergence or re-emergence of not only DF, but malaria and other vector-borne diseases. For instance, new innovative vector control methods (IVCMs) such as those found in the Innovative Vector Control Consortium (IVCC) were devised to improve household-based insecticide spraying that had not been effectively sustained in many DF endemic countries (Hemingway et al., 2006).

A second standard strategy is the 2010 WHO Asia-Pacific Strategy for Emerging Diseases (APSED), an Asia-Pacific regional context-based strategy for the response and control of emerging diseases (2011a). This strategy strongly emphasizes a public health directive for disease response capacity building including skilled staff, resources and laboratory/diagnostic equipment, and surveillance and monitoring of emerging diseases. However, Murray et al. (2013) highlighted issues faced by countries in the region that are yet to successfully implement this strategy due to issues including political inability to improve public health systems' (PHSs) capacity.

The 2011 WHO guidelines for DF diagnosis, treatment, prevention and control, including targeted vector control, was the third example of a standard model used for the promotion of comprehensive DF control (2011b). This standard model is necessary to achieve maximum DF control by integrating laboratory-based surveillance, vector control, clinical case management, environmental protection and social communication. A similar model by the Pan American Health Organization (PAHO, 2014) in all countries reporting DF was the Integrative Management Strategy for Dengue Control and Prevention (IMS-Dengue).

The recent Global Dengue Strategy (GDS) 2012-2020 features specific goals of 50% reduction in DF mortality and morbidity by 25% by 2020, and of building adequate DF response capacity within PHSs with a special focus on community empowerment and social mobilization (WHO, 2012). This strategy has re-emphasized the importance of advocating for communities to take ownership and sustain home-based DF control and prevention (Park & Lloyd, 2004). The strategy further coincides with the United Nations Developmental Program (UNDP) Goal 3 for all to sustain healthy living by 2030 (McPake, Russo, Hipgrave, Hort, & Campbell, 2016).

1.2 Dengue epidemiology

Ferreira (2012) found that, geographical expansion of the DF disease and the *Aedes* vector was evident; however, the true estimate of the total global burden of DF remains unknown. This scenario may be attributed to the constraints inherent in the public health surveillance systems and unique challenges specific to DF control. The variations in DF case definitions and unreliable interpretation of generated evidence may manifest because of poor diagnosis and codifications, low laboratory capacity and non-uniformity in DF response programs among countries (Ooi & Gubler, 2009). Such a scenario may not only demonstrate gross lack of laboratory-based diagnostic services in many DF reporting countries (WHO, 2009b), but may also imply that initial medical screening in the febrile stage are often ignored as most patients recover without treatment (Whittaker, Berquist & Buttsworth, 2013).

1.2.1 Global trend

Ferreira (2012) has been critical of the differences in the reporting of the DF disease and suggests that various factors such as socio-economic and geographical conditions across different world regions and countries may have influenced such differences. The spread of the *Aedes* mosquito over vast distances has led to a resurgence of DF epidemics and the emergence of severe forms of DF in the last two decades (Kyle & Harris, 2008). As such, the number of countries reporting DF cases has increased to 125 including PNG as compared to the 1950s where just less than 10 countries reported the disease (Ferreira, 2012).

It has been estimated that, between 2.5 and 3.6 billion people, which is over 50% of the global population, live in DF risk countries including travellers exposed to the risk of DF transmission (Ferraira, 2012). Of the estimated 50-70 million annual febrile DF cases, more than 2 million cases progress into both critical and convalescent phases with more than 21,000 reported deaths (WHO, 2009b). While more than 90% of all severe cases were reported in under-five children, febrile cases of DF were more prevalent among the older population group (Hammond et al., 2005).

Hairi et al. (2003) estimated DF mortality rate at 10% over a three-year projection from 7.3% per 100,000 between 1995 and 1998 to more than 16% in the 1998-2001 period, which would have reached an estimated increase of about 20% in 2010 given the trend in prevalence (Figure 3.3-D column graph). Although such projections may sometimes under-estimate periodic improvements such as the reduction in mortality in 0-14 years old children to less than 50% (WHO, 2011b), it provides a scenario of challenges and the need for maintaining reliable DF surveillance and monitoring systems (Whittaker et al., 2013; WHO, 2009a).

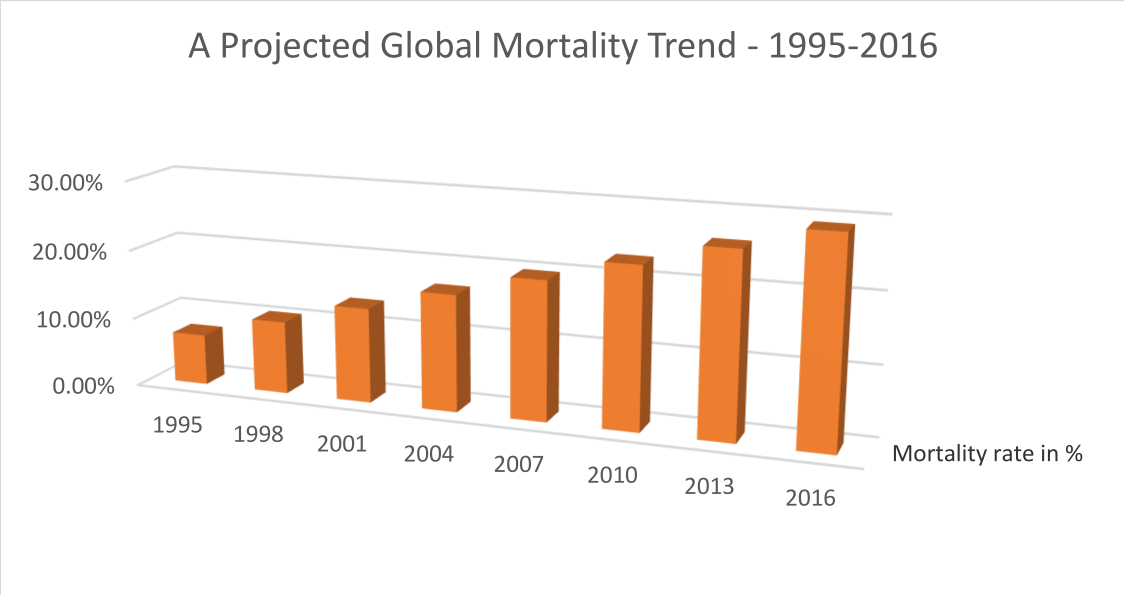


Figure 3. A 3-D column chart illustrating a projected three-year increase in the mortality rate per 100,000 population from 1995 to 2016 based on the base-line estimates by Hairi et al. (2003).

Based on this evidence, DF has expanded its endemicity in territories new to DF as the number of DF reporting countries have dramatically increased. Although, the trend of DF transmission and its spread is globally significant (Murray et al., 2013), many countries lack the necessary resources to maintain DF surveillance systems and reporting networks hence, an accurate estimate of the global burden of DF remains unknown (Ferreira, 2012). Other challenges may not only arise from the technical program design and implementation within PHSs, but may also result from lack of active stakeholder participation, social mobilisation, community empowerment, which are key to address socio-economic and cultural risks associated with DF transmission (Dearing, 2009; Davies, 2017).

1.2.2 Regional DF comparisons

In terms of world regional comparison as shown in Figure 4, almost 75% (n=1, 663276/2,224,108) of global DF infections including 1,194 DF-related deaths had been reported in LA (Murray et al., 2013; Ferreira, 2012; PAHO, 2011). Also in that year, the South-East Asia Region (SEAR) and Western Pacific Region (WPR) reported 8.5% (n=187, 333) and 15.9% (n=354, 009) of the total global DF cases, respectively along with 1, 075 reported deaths between them (WHO, 2011b). A re-emergence has recently been reported in the United States of America (USA) after many decades of DF absence (Ferreira, 2012), thus illustrating a high magnitude and trend of DF endemicity and its expansion in the region (Guzman et al., 2010).

The sparse DF surveillance data and under-reporting of DF cases, including those from significant outbreaks in many countries of the African region may have led to the difficulty to establish a more accurate estimate of DF prevalence (Ferreira, 2012). However, 22 African countries reported DF incidences with strong suspicions of the presence and circulation of most or all the four DF (DENV1-4) serotypes (Ferreira, 2012). Such evidence of repeated report of DF endemicity in many of the African countries in limited serological surveys may indicate under-reporting despite potentially overwhelming presence and circulation of multiple DENV serotypes in the African region (Murray et al., 2013).

In the European continent where geographical-based DF endemicity is yet to be fully established, the *Aedes* vector proliferation is looking more feasible than ever. For instance, a confirmed outbreak of DF on the Madeira Islands of Portugal in 2012 with sporadic cases of 2013 leading up to a cumulative total of 2164was reported, of which 78 cases were imported by travellers (Murray et al, 2013). Such evidence may suggest that DF serotypes carried by travellers are being introduced into the European region including the transportation of the *Aedes* mosquitoes carried in used tyres in international trading ships, such trend compounded by climate change.

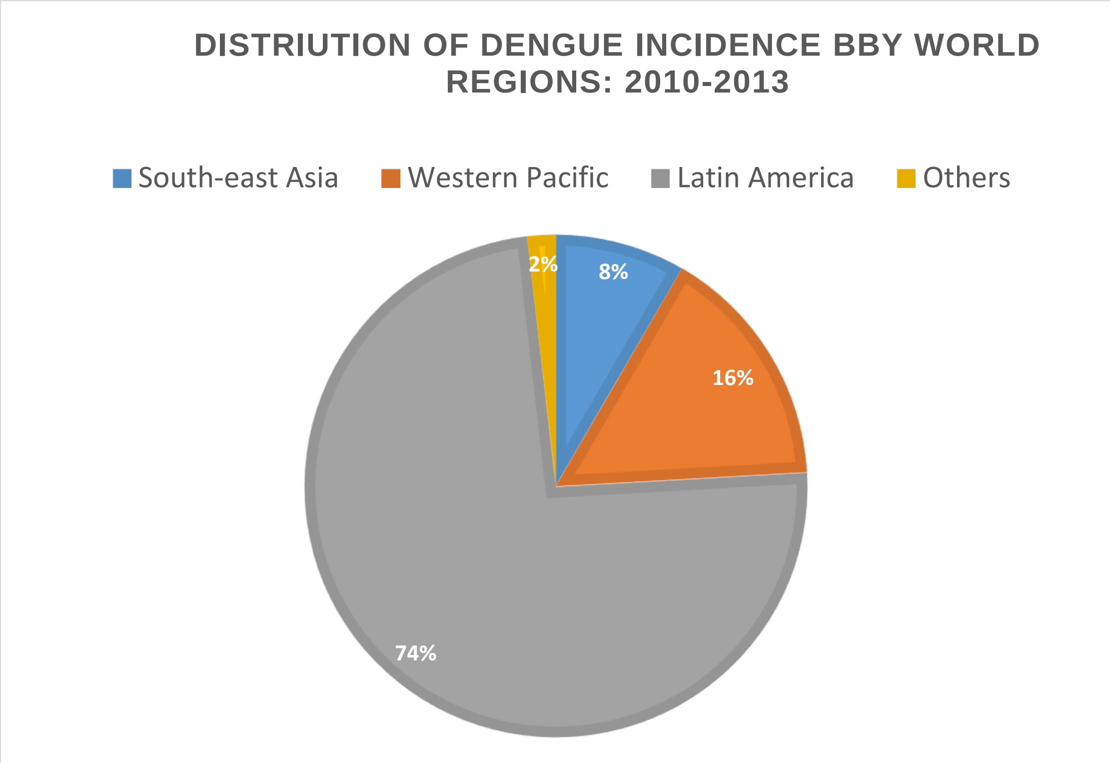


Figure 4: A pie chart showing a three-year (2010-2013) cumulative distribution of DF incidences between world regions. ***Other*** represents Eastern Mediterranean, Africa & European regions). **Source**: Data by Murray et al. (2013).

About three-quarter of global DF infections between 2010 and 2013 have been reported in LA which may also demonstrate their governments' commitment to prioritize DF control, surveillance and reporting (Murray et al., 2013). Consistent reporting of epidemiological data on DF in this region may also demonstrate an on-going support from the PAHO in implementing the Integrated Management Strategy for Prevention of Dengue (IMS-Dengue). IMS-Dengue, according to the PAHO (2014) is a DF control model which promotes improvements to DF surveillance by laboratory networks, clinical case management, IVM, environmental management strategies and social communication.

1.2.3 Dengue Fever (DF) in Papua New Guinea

Like many tropical countries that incur high rate of DF epidemics (Simmons et al., 2012), PNG reported its first series of epidemics during post-World War II years of 1944, 1971 and 1978 (NDOH, 2010a), which was responded with entomological investigations undertaken in four regional locations between 1987 and 2008 (Kitau, Samiak, Guldan& Machine, 2016). All four studies confirmed the circulation and presence of the DF DEN1, DEN2, and DEN3 vector serotypes (*Aedes Aegyti, Aedes albopictus* and *Aedes scutellaris*) distributed throughout PNG, with less circulation in the highlands (Figure 5).

Figure 5. Map of PNG showing the distribution of dengue vector

***Note.*1.Source.** National Mapping Bureau of PNG. Retrieved 27/02/2018 fromhttp://hotel-ruegen.info/papua-new-guinea-map.html

2. Inset: *Aedes* mosquito distribution in PNG based on data from NDOH (2010a), Kitau et al. (2016) and Luang-Suarkia et al. (2017).

An Australian-based investigation in 2003 also confirmed a DEN2 serotype has been introduced by a PNG national in an Aedes *Aegypti* mosquito infested Cairns (Australia) neighbourhood (Hanna et al., 2006). Although, evidence of overwhelming presence and circulation of dengue vector has been established (Luang-Suarkia et al. 2017), the true extent of dengue in PNG remains unknown (Kitau et al., 2017) despite a dengue control program that was started in 2012 following a policy directive approved in the PNG National Health Plan (NHP) 2011-2020 (NDOH, 2010a). The target of the PNG NHP 2011-2020 on dengue control is to have in place a full-fledged dengue program including a vibrant surveillance system in PNG by 2020, which is also the goal of the GDS 2012-2020 (WHO, 2012).

Despite the lack of surveillance data on DF epidemiology in PNG (NDOH, 2010a), a few independent studies have established an association between age, socio-economic factors and geographical location and DF transmission. For instance, both Senn et al. (2017) and Anga et al. (2013) found young age to be a risk factor in PNG while, Kitau et al. (2016) and Luang-Suarkia et al. (2017) found semi-urban settlements featuring uncontrolled population explosion due to mass rural/urban drift in search of better socio-economic opportunities and practicing poor rubbish disposal and low rural coastal regions as high-risk areas. As such, this study can confirm that, young children and those living in uncontrolled urban settlements and low coastal regions as vulnerable populations at increased risk of DF transmission in PNG.

1.3 Rationale for study

Drawing from the background analysis, the re-emergence of DF is now an important public health phenomenon that threatens health of the global community. Historically, DF transmission was only confined to tropical and sub-tropical world (Gubler, 2002); however, with the increase in climatic temperatures, international travel and trade, its re-emergence is expanding to new geographical zones (Murray et al., 2013)..

This study chose PNG as its study location not only because of its geographical risk as a tropical country, but also because of the specific issues faced by PNG in relation to DF. First, although a specific DCP has been highlighted in the PNG NHP of 2011-2020, DFhas not been fully recognized and often overshadowed by malaria under the “Malaria and Other Vector-Borne Diseases” program (NDOH, 2010a). As such, the vague visibility of the true prevalence of DF on population health in PNG will continue to impact on population-based DF control and prevention if DF is treated as an ordinary health problem into the future. This is despite evidence to the contrary that DF is a significant burden in this country. Second, PNG is a country with significant socio-economic burdens, with its population facing poverty and lack of public health infrastructure. This work is intended to highlight the need for international and national response to the issue of DF.

This study is intended to create the basis for establishing information on how the recent policy on DF control in PNG had progressed and to advocate that the issues be swiftly addressed. However, the particular circumstances of PNG need to be considered as the existing practice policies that have been discussed earlier in this chapter might not cope with the overarching impact of the increasing trend of globalization and climate change on the transmission of vector-borne diseases (Murray et al., 2013). This study will therefore aim to investigate and provide solutions may not only include poor access to DF control opportunities in PNG, but to also determine the impact of the socio-economic, environmental and cultural influences on DF transmission and its preventive measures.

An important intention of this study is that, its outcomes can be used as a benchmark for communicating evidence necessary for developing alternate or new practice policies not only for DF control but, also as a standard practice for all vector-borne diseases. For instance, a thorough examination of literature on the impact of climate change, globalization and trade on DF transmission could shed some light on improving public health measures for the control of all vector-borne diseases (Murray et al., 2013). This study will also aim to quantify DF response capacity within the PNG PHS as a necessary policy landmark necessary for the creation of better equitable and inclusive DF control measures to reach both urban and rural areas. It will also review the feasibility of IVCMs trialled or implemented in other dengue-endemic countries to establish evidence for recommending alternate policy options for improving DF control in PNG.

In this light, the two research questions are:

> *(1) In light of the socio-economic, cultural and environmental determinants impacting on DF control in PNG, how successful has the PNG DCP been?*
>
> *(2) What IVCMs that were either trialled, piloted or implemented in other dengue-endemic countries, may be applicable in a PNG context to improve DF control and prevention?*

1.4 Study organization

Based on what has been discussed and deliberated in this Chapter (1); the rationale for an appropriate methodology is outlined in chapter two as well as techniques for data extraction and their analysis. The formulation of the research question and study objectives are necessary elements for influencing selection of an appropriate study methodology. The literature review section is divided into two separate chapters (3 & 4) which include respective reviews on the PNG DCP and IVCMs that were either trialled, piloted or implemented in other dengue-endemic countries. Chapter three on PNG DCP forms the first part of the review to investigate if there are underlying factors both within and outside of the PNG PHS to influence the lack of successful DF prevention and control in PNG for many decades despite DF been a well-established public health problem since the post-WWII period. Likewise, Chapter four forms the second part of the review targeted at appraising each IVCM of their implementation in other dengue-endemic countries with similar socio-economic, environmental and cultural similarities to PNG.

Chapter five summarises the findings of Chapters 3 and 4 to enable overall conclusions to be drawn and key recommendations to be made. This overall review of the DF situation will highlight existing issues that were identified in both reviews including the lack of DF response capacity within the PNG DCP and strengths and weaknesses of each IVCM. Towards the conclusion section, the study will make key recommendations with new or alternate practice policy options to improve DF control in PNG.

1.5 Summary

Globally, DF fits the criteria as an important global public health notifiable disease that requires attention from all government sectors for maximum control of this opportunistic infection that is common in young children, pregnant mothers and sick adults whose immunity has been compromised. The state of the DF disease brings many challenges not only in clinical and laboratory-based diagnosis, but also low community understanding about DF and its home-based control measures. There were also variations in DF surveillance data in many dengue-endemic countries and regions including PNG, indicating a lack of successful implementation of the global WHO recommended DF response models.

At the regional front, LA reported almost three-quarters of the total regional-based epidemiological DF updates for the 2010 DF year as compared to other regions of the world (WHO, 2011a; PAHO, 2010). The reasons for such huge variations between LA and other DF reporting regions of the world may suggest that many LA states prioritise DF control by successfully implementing WHO recommended DF control models. It is also evident that the PAHO ensures each LA State successfully implements the integrated IMS-Dengue model featuring all aspects of DF control including clinical and public health interventions, epidemiological and entomological surveillance, IVCMs, social mobilisation and environmental protection.

PNG-based DF prevalence remains vaguely invisible in light of the poor surveillance of its incidence and related mortality despite DF being a well-established vector-borne disease in PNG since the post-WWII period. The PNG PHS has grossly neglected DF control many decades until 2012 when a single DF-specific response plan was born as a policy directive of the PNG NHP 2011-2020, although that appears to have achieved very little (NDOH, 2010a). For instance, there is a poor reporting outcome due to the absence of DF-specific disease identification on the daily out-patient tally sheets (NDOH, 2001). Other major issues with DF control in PNG include, but not limited to lack of diagnostic skills among clinicians and laboratories and lack of community mobilisation and empowerment for effective sustainability of home-based DF control.

In terms of study outline and its organization, this chapter (1) starts with a general background analysis of the DF situation including historical perspectives, definition and clinical staging, risk factors and the rationale of this study. In the methodology section (chapter 2), a research question and objectives including specific benefits for target population will lead to identify an appropriate review methodology. Following the undertaking of the two literature reviews respectively on the PNG DCP and feasibility of IVCMs in light of the socio-economic and cultural influences, a discussion of findings and drawing up of conclusions will create the academic space for making new recommendations with an aim to improve DF control in PNG.

Chapter Two: Methodology for study

2.1 Introduction

This chapter detailing methodology, as explained by Hanson (2006), starts with a research question as a key primary step in influencing the identification of a suitable research methodology. Given the significance of this study following the background situational analysis in chapter one, it then sets out potential study objectives to benefit both the PNG DCP and population at large. As highlighted by Kothari (2004), undertaking this strategy may not only complement the role of the research question to identify an appropriate methodology; rather, it also supplements the role of the chosen methodology to adequately answer the research question.

2.1.1 Research questions

The research question prior to undertaking a review process according to Johnson and Onwuegbuzie (2004) provides an underlying potential for influencing the selection of a methodology and provides guidance for the compilation and analysis of data. As initial methodological steps in research (Kothari, 2004), the following two questions were formulated for this study based on evidence generated from the background situational analysis: *(1) "In light of the socio-economic, cultural and environmental determinants impacting on DF control in PNG, how successful has the PNG DCP been?" (2) "What IVCMs that were either trialled, piloted or implemented in other dengue-endemic countries, may be applicable in a PNG context to improve DF control and prevention?"* As argued by Nichter (2008) about cultural, social and political barriers in global health, this question does not only beg an explanation on why there was lack of government attention for DF control in PNG; rather, it also queries which IVCMs were appropriate to enhance the effectiveness of the PNG DCP under current conditions.

Based on the explanation by O'Leary (2004), these research questions were formulated with an aim to enhance the purpose of study to identify an appropriate review methodology. In addition, these questions may further provide the necessary space for developing additional questions for further exploration and examination of data to establish evidence as new knowledge to be gained based on what is already known. For instance, Khurshid, Bannerman and Staples (2009) explained that study questions aim to ensure initial stages of study methodology are designed to influence discussions through to the end, while minimising potential biases based on the researcher's opinions.

2.1.2 Study objectives

Based on the author's understanding of the DF background situational analysis, achievable objectives were formulated which could influence the identification of an appropriate study approach. These targeted objectives were not only aimed at improving the PNG DCP through practical suggestions, but also provide a list of options that are theoretically linked to a critical epistemology (Nicholls, 2009). Based on the suggestions by Grant and Giddings (2002) and Grant and Booth (2009), this study anticipates the creation of a conceptual basis for gaining an insight understanding into the public health policy practice in a PNG context.

As explained by Keele (2007), the purpose of undertaking a critical literature review is to determine what has already been written and the application of key concepts in DF control and prevention in PNG. This review also aims to establish relationships or patterns between risk factors and DF transmission to identify both strengths and weaknesses within the public health chain of DF control in PNG. As highlighted by Durlak and DuPre (2008), the undertaking of such a critical review will identify gaps or conflicting evidence in the literature of current practice policies.

Relevantly for this study, an important goal of the GDS for 2012-2020 is to reduce the high rate of transmission of home-based mosquito-borne pathogens by improving the control of household vectors (WHO, 2012). In order to achieve this goal in PNG, it is first necessary to gain an understanding of the PNG DF phenomenon. Hence, it will be outlined that these anticipated objectives can only be adequately achieved through the application of a critical literature review methodology influenced by a critical epistemology capable of providing adequate theoretical space for advocating for an improved social mobilization, empowerment and community participation, the government's social responsibility for its citizens.

I. The first objective is to understand why and how DF has been neglected for many decades despite been an established public health disease since the post-WWII period, and to what extent has the PNG DCP been achieved.

II. The second objective is that new knowledge and understanding about how socio-economic, cultural and environmental factors are influencing not only DF transmission, but also affecting its prevention and control efforts in PNG. For example, community is educated to cease a cultural practice that influences mosquito breeding including DF transmission when water drinking containers belonging to death relatives are left over their burial sites within home environments.

III. The third objective is to establish an understanding about the relevance of IVCMs conducted in other countries to improve DF control in PNG in light of its current socio-economic, cultural and environmental conditions. For instance, communities are educated on the safety of those insecticide-based IVCMs whose chemical strengths (pyrethroid formulations) have been repurposed (reduced) to minimize risk to the natural environment.

IV. The fourth and final objective of choosing a critical literature review is to understand how social mobilization, empowerment and community participation may be possible under the current PNG socio-economic, cultural and environmental contexts.

2.2 The critical paradigm

In terms of philosophical perspectives, Lincoln, Lynham and Guba (2011) explained that, methodological processes are knitted and underpinned by a philosophy as a theoretical framework that provides clear research directions. A philosophical worldview plays the role of a research paradigm to demonstrate methodological appropriateness of its investigative features to reach a hypothesis, answering a research question or achieving anticipated objectives (Mertens, 2007). As explained by Lincoln et al. (2011), selection of a research methodology informed by critical theory is useful for illuminating influences of structural or systematic factors including capacity of the PNG DCP and feasibility of IVCM application under current PNG socio-economic, cultural and environmental conditions

An epistemology, according to Creswell & Clark (2007), is a term often used along with research paradigms as an assumptive knowledge which individuals use for explaining the existence of realities based on experience. An epistemological focus may be guided by a critical theory in using the "why and how" questioning techniques to drive discussions deep into social issues including inequality based on human voices raised by deprived populations (Myres, 2013). Hence, the significance of this study warrants the selection of a critical paradigm to underpin the critical literature review (CLR) to examine and establish evidence of potential barriers impacting on the effectiveness of PNG DCP necessary for advocating on behalf of the PNG population for better and inclusive health practice policies to address issues associated with deprivation of access to public health care (DF control and prevention).

The mode for this study is a desk-based CLR to examine existing government documents, literature and research rather than undertaking an individual-based field study where data collection and analysis are sometimes biased towards personal observation and opinion. For instance, through the undertaking of a CLR for this study, adequate literature is reviewed to establish or solicit adequate evidence why DF control and prevention in a PNG context was significantly poor. Thus, such evidence can be properly justified by a CLR to highlight the need for social justice to prevail through workable policies to improve accessibility to DF control and prevention information through social mobilization, empowerment and participation.

2.2.1 Why choose CLR?

A critical literature review according to Rossi, Lipsey and Freeman (2003) is a systematic evaluation of an issue of interest by analysing and reviewing published literature including academic and scholarly data sources, and government and agency policy documents. This aligns with a critical approach can whereby underlying socio-economic issues including unequal access to health care by deprived communities that can be advocated for government (political) intervention can be revealed. Grant and Booth (2009, p.93) defined the purpose of a critical review as:

> A critical review aims to demonstrate that the writer has extensively researched the literature and critically evaluated its quality. It goes beyond mere description of identified articles and includes a degree of analysis and conceptual innovation. An effective critical review presents analyses and synthesizes material from diverse sources.

As such, this study anticipates benefits for the PNG DCP, especially for those exposed communities to risk of DF transmission when new understandings with new ways are established. As explained by Myres and Klein (2011), concerns raised and advocated by members of the community to improve the lack of access to socio-economic and health care opportunities are often constrained by various forms of social, cultural and political dominations. As such, the utilisation of a critical literature review is important, especially for highlighting the realities of the fragmented PNG DCP and appraising the effectiveness of each IVCM that can be implemented in PNG to improve DF control in PNG under the current PNG conditions.

As explained by Berg (2004), a critical review will include study structures, methodological styles and the researcher's own conclusions enhanced by the usage of specific narrative analysis of data based on reasons and sites of program implementation. The intention is that, by undertaking a critical examination of the social aspects of existing policies and practice guidelines, new issues affecting the health of vulnerable populations and recommendations for solutions will become apparent (Rowson et al., 2012). Therefore, a critical literature review fits this criterion as a relevant approach not only to answer the research question, and that the expected objectives are achieved, but also provide opportunities for improving existing public health policies and practice guidelines.

2.2.2 Strengths and weaknesses of a CLR

Although, Mertens (2007) was critical about the lack of a major theory framework to back the critical literature review in its arguments compared to more structured approaches, Grant and Booth (2009) vigorously highlighted its potential for creating wider theoretical space for justifying the creation of new practice knowledge. For instance, the use of "who and why" questions to dig deeper into underlying issues based on the "what", "where" and when" situations were necessary to establish underlying social issues that requires government intervention (Mertens, 2007). Hence, the scope of this study may require a critical literature review to have the necessary theoretical strength to do a deep examination of literature into underlying realities impacting on the PNG DCP in light of the socio-economic, environmental and cultural barriers, and appraise feasibility of IVCM application to improve DF control in PNG.

A critical review applies only a pragmatic approach that often lack philosophical space (Keele, 2007). This can be compared to systematic reviews which operate under strict guidelines and evaluate the quality of the work. However, rather it draws conclusions about the effectiveness of policy implementation protocols (Mansuri & Rao, 2004). In a CLR, potential biases are carefully tracked in written documents, including researcher's own personal views about practice policies on sensitive social issues (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). For instance, a CLR also haspotential to identify biases in public health literature such as unequal accessibility to DF prevention measures disproportionately high among deprived communities (Myres & Klein, 2011). Hence, by contemplating on such socio-economic and health care rights deprivation which might directly impact on DF transmission, a CLR can advocate for changes in social policy to attract government (political) intervention through donor funding to empower communities and families take ownership and sustain DF control in PNG.

On a more practical level, the critical literature review does not allow collection of primary data in PNG but rather desk-based research to explore evidence from local state documents, published journals and books on DF. However, this was to fit in with the timelines for study and scope of this dissertation. The other reason is the absence of reliable dengue surveillance in PNG was less likely to guarantee access to reliable data for field study research rendering me to a desk-based critical evaluation of the PNG dengue program and appraising the feasibility of IVCMs based on a PNG context. Such as a review appears more appropriate for the PNG DCP and the identification of appropriate IVCMs in this context than other systematic reviews.

2.3 Study design

The organisation and design of the review is based on the Figure 6 showing steps for undertaking the expected activity for the CLR starting with a search strategy that includes key words, search machines including Google scholar, Pub Med and Medline as databases to identify relevant references. The second step is to use an inclusion criterion to reduce and narrow sample size to a more refined sample that can at some point be used inter-changeably between the two reviews. Following each review, conclusions can be made for further discussions to determine new policy options that might be considered relevant for improving DF control in PNG socio-economic, environmental and cultural contexts.

Ethical approval to conduct this study was not necessary because the study is a desk-based investigation using online and manual learning facilities available at the AUT University Library.

Flow chart of study design

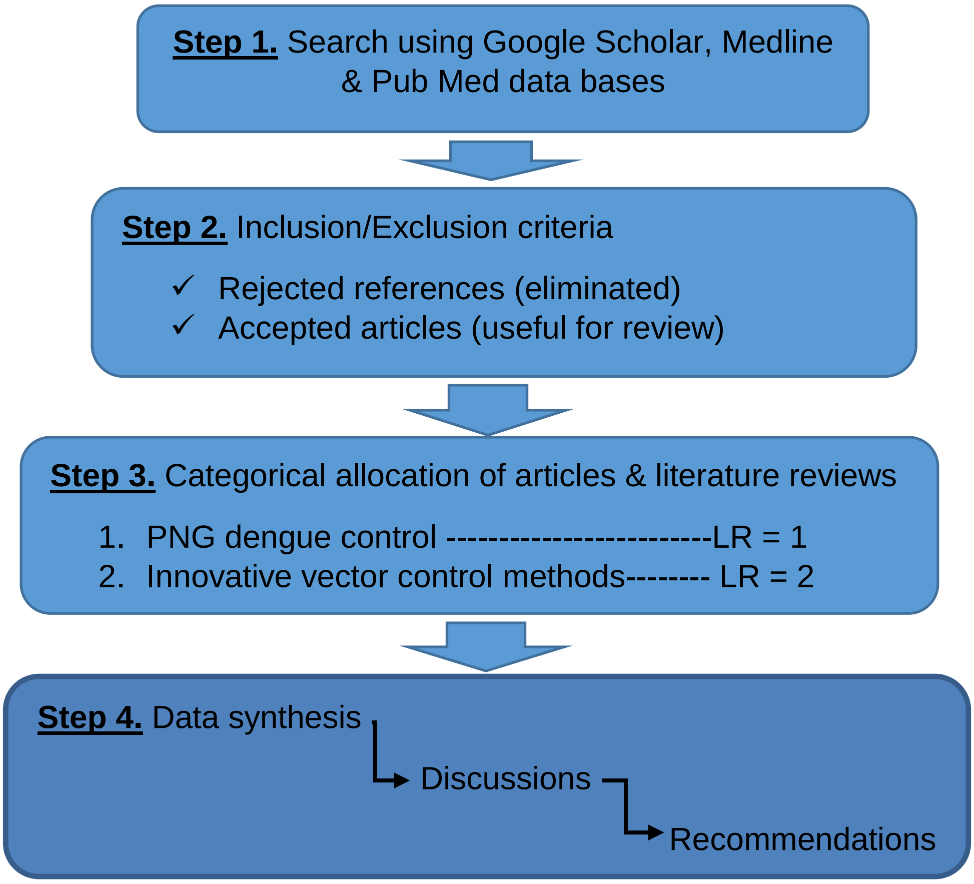


Figure 6. Flow chart demonstrating the flow of the study design

2.3.1 Literature search strategy

An online AUT Library search retrospective to 2000 to the 17/09/17was undertaken using Google Scholar, Pub Med and Medlineas internet search machines to identify relevant articles that might include both scholarly and non-scholarly state documents and agency reports on DF transmission and control. Therefore, journal articles, primary government documents and other grey literature were included as relevant. Key search terms used in the search include, “dengue fever,” “dengue control,” “dengue prevention,” “vector control,” “PNG dengue control,” and “innovative vector control methods.” The search was extended to capture risk factors including references on the impact of climate change, socio-economic, environmental and cultural factors not only on DF but also on other vector-borne diseases.

Table 1. Literature search strategy

Search terms	**Pub Med**	**Google Scholar**	**Medline**	**Total references**
Dengue fever	2624	43	148	2820
Dengue control	1183	7	24	1214
Dengue prevention	899	18	98	1015
PNG dengue control	13	0	2	15
Innovative vector control methods	18	118	13	149
Climate change, socio-economic, cultural and environmental risks	167	811	12	1110
Total references	**4894**	**1009**	**279**	**6182**

Based on Table 1 (above), the search showed overwhelming results with the identification of a total number of 6182 raw references (Pub Med=4,894; Google Scholar=1,009; Medline=279) which were reduced using an inclusion criterion (see 2.4.2). The key word “dengue fever” generated the highest number of references with 2,820 while the lowest number was 15 generated by the key term “PNG dengue control”. In comparison, the rest of the key words generated a sub-sum references of 3,815 (dengue control=1,214; dengue prevention=1,015; climate change socio-economic, environment and cultural factors=984; and innovative vector control methods=149).

2.3.2 Inclusion criteria

Given the increasing literature on DF transmission and control in recent years" (Murray et al., 2013), articles to be included in the review must be published "after 2000" as the set date. An inclusion criterion was used to reduce the volume of references to a more refined sample size which must be in the English language, and as explained by Kitchenham (2004), this simple inclusion criterion was able to eliminate a huge number of irrelevant articles with an aim to narrow the research domain rather than being broad-based.

Of the total 6182 references identified, only 50 articles fully met the inclusion criterion with 6078 irrelevant references were excluded in the first elimination. Abstracts of the 104 retained articles were briefly viewed from which 54 were further excluded as they were mostly state documents, irrelevant of non-scholarly reports of other dengue-endemic countries. Full texts of the final sample of 50 articles were read and, using a table, summary of data related to study purpose or aim, methodology, results or conclusions and recommendations were documented.

Except for newspaper advertisements, data was also collected from other sources including cited references found in bibliographies of articles selected for the review to supplement evidence on DF transmission, control and prevention. Consideration was given to include literature covering not only DF, but to also include references on other vector-borne diseases that were re-emerging in light of changing climatic temperatures and weather patterns. For instance, studies by Murray et al. (2013) on the "Epidemiology of dengue: past, present and future prospects" and Lang et al. (2015) on "climate change in Papua New Guinea and its impact on disease dynamics" were included for review to cover for other vector-borne diseases.

2.3.3 Data analysis

Full texts of the remaining 50 articles were read through and data was collated based on sub-themes and supplementary questions. Data analysis was undertaken using a thematic analysis to get to the bottom of sensitive issues to shift government intervention. Results of study will be documented in themes in each review with an aim to answer the two research questions and providing assurances that, expected outcomes can be achieved if the government is convinced by the outcome of this research. The potential of using these findings as evidence to justify the argument is that, it is directed by a critical epistemology to highlight social issues that require political intervention.

2.4 Summary

A research methodology provides a link between a philosophical worldview and the collection of data and analysis to test a hypothesis or answer a research question. Consideration was given to the research question, study objectives and other factors such as the researcher's own influence prior to selecting an appropriate study methodology for directing data collection and analysis. This study acknowledges these factors as they underpin the research process to answer the research question and achieve the study objectives including expected outcomes into the future.

The following two research questions as first steps in the determination of a suitable research methodology are: *(1) "In light of the socio-economic, cultural and environmental determinants impacting on DF control in PNG, how successful has the PNG DCP been?" (2) "What IVCMs that were either trialled, piloted or implemented in other dengue-endemic countries, may be applicable in a PNG context to improve DF control and prevention?"* It does not only aim to review the PNG DCP but also to appraise the effectiveness of the IVCMs and how feasible they would be sustained in the context of PNG socio-economic, environmental and cultural conditions. The study objectives were set up in accordance to the GDS2012-2020, which focuses on community-based

DF control and prevention through social mobilization, community empowerment and participation (WHO, 2012).

Based on the background analysis including the research question and the setting up of study objectives, a critical literature review was considered for the undertaking of the two evaluations. This study anticipates that investigations into the most critical areas including the lack of DF prevention activities in the communities will be made visible for public health interventions. One significant benefit in undertaking a critical literature review will be that, communities lacking socio-economic opportunities or facing environmental and cultural challenges may be advocated, not only for government's public health intervention but, also for inclusive and participatory DF prevention at the community level.

To make this study more significant, a critical review approach aims to establish evidence of how effective the PNG DCP was in view of both the NHP 2011-2020 and GDS 2012-2020 goal on DF and other vector-borne diseases by 2020. The critical review can be also used as a medium for social mobilisation and community empowerment and advocating to the government and the general population to recognise DF as an important public health disease in PNG. As such, this review process will not only highlight the existing critical issues in the PNG DCP, but also aims to attract active community participation to sustain cost-effective community-based vector control methods such as proper rubbish and waste disposal practices.

A study design featuring a search strategy, inclusion criteria, data collection and analysis was strategized in a way that the review including data collection and analysis do not side-tract from the topic, research question and study objectives. For instance, of the total 6182 references identified from the search, only the relevant articles meeting the inclusion criterion were retained with majority of irrelevant articles were eliminated through first and second elimination stages. The final sample of 50 references of which, 20% (10) were PNG DCP-related articles compared to the 80% (40) of the sample were IVCM-related would form the core of the CLR and supplemented by their respective bibliographies (reference list). Data analysis will be guided by a narrative synthesis based on themes and supplementary questions to get to the bottom of the issue under study. Please see summary study design flow chart in Figure 7.

Summary flow chart of study design

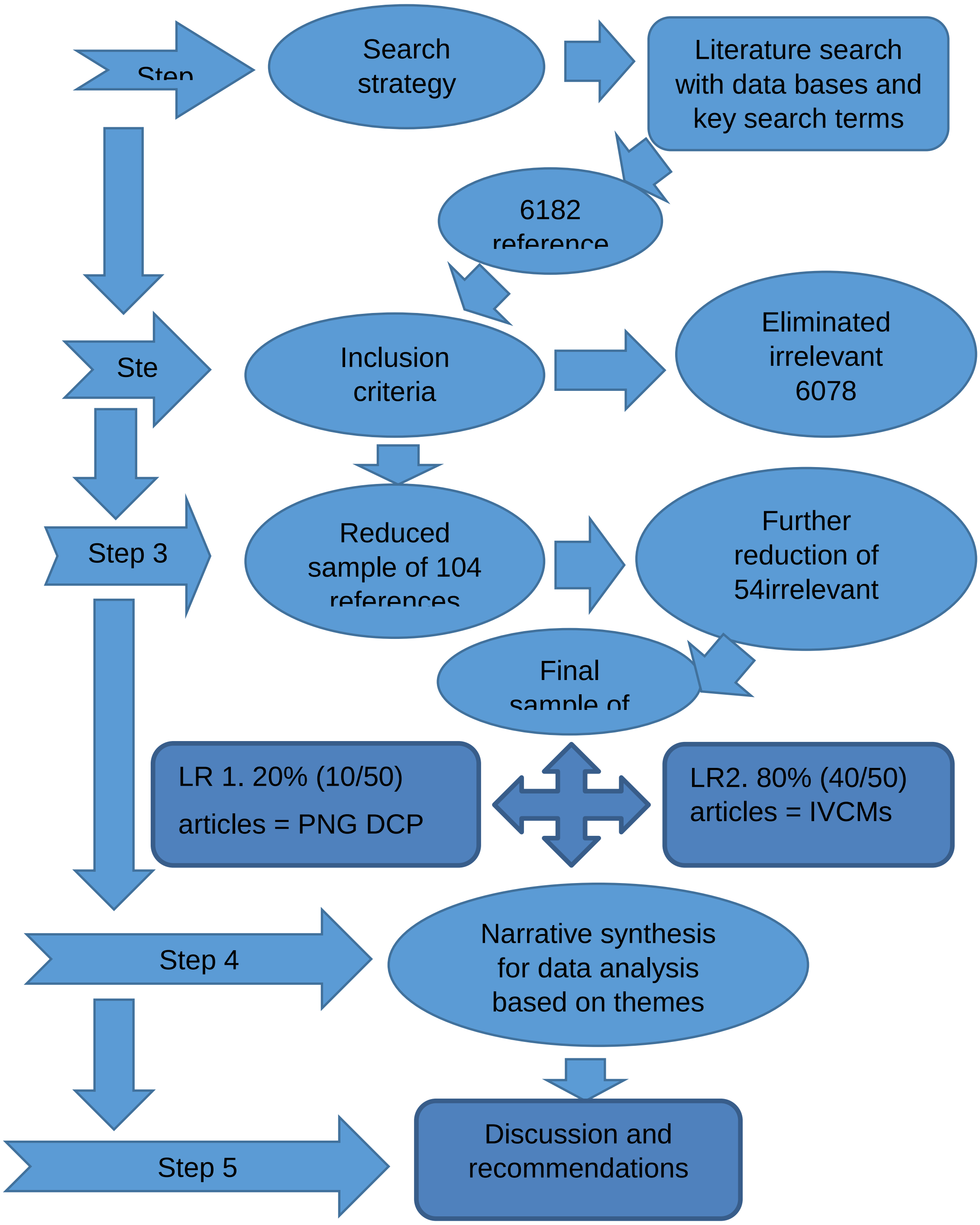


Figure 7: Summary of a 5-Step Flow Chart - Study Design.**Key: LR1** = Literature review 1 & **LR2** = Literature review 2

Chapter Three: Literature Review 1. Review of PNG Dengue Control Program

3.1 Introduction

This chapter is the first of the two literature reviews and evaluates the effectiveness of the PNG DCP and to establish the extent of both successes and failures. This review does not only aim to examine the extent of the program success, but also identifies potential socio-economic, cultural and environmental determinants that impact on achieving maximum DF control. As highlighted by Peredo and McLean (2006), the context of the study requires a critical examination of factors associated with PNG DCP and the identification of the existing gaps within its' practice policies as evidence for suggesting alternate policy options to improve DF control in PNG.

The supplementary questions have been raised as strategic links to guide this review to conduct an in-depth exploration and investigate potential issues impacting on the PNG DCP. Given the history of DF in PNG and the initial response strategies implemented to control the first reported series of DF epidemics, careful discussion of these questions is important to establish evidence necessary for developing better public health policies.

1. What is the current public health practice policy of the PNG DCP?
2. What are the current issues in the PNG DCP?
3. What are researcher's views about these issues and how can they be addressed?

In the PNG context, the anticipated outcomes from this review will not only provide the necessary theoretical space for suggesting new practice policies, but will also advocate for social mobilization and empowering of community members to sustain community-based DF control. As suggested by Copper, Riel and Hasan (2011), an insightful exploration is undertaken to assess the impact of socio-economic, environmental and cultural factors on the

PNG DCP. By analysing the contexts as well as the processes by which the program was implemented, the extent of its impact in the communities can be deliberated against both PNG NHP 2011-2020 policy directions on the PNG DCP and the WHO GDS 2012-2020 goals.

3.2 The PNG DCP – a situational analysis

Due to the increasing threat of wide-spread DF epidemics and outbreaks driven by the increase in climatic temperatures and socio-economic factors (Murray et al. 2013; Banu, Hu, Hurst & Tong, 2011), a plan to implement a DF-specific response program was captured in the PNG NHP 2011-2020 (NDOH, 2010a). The aim of creating a single response program was to influence the PNG government to implement comprehensive DF control strategies such as the APSED model to prioritize attention and resources for adequate DF control (WHO, 2011b). An APSED is an example of a generic model used as a road-map to achieve the 2005 International Health Regulations (IHRs) capacity requirement (Gubler, 2002; WHO, 2008a). If such comprehensive DF response strategies are not considered in PNG, community-based control and prevention of DF epidemics may become unsustainable with an absence of a reliable DF surveillance system.

The initial undertaking of the PNG DCP in 2012 was by a policy directive from the PNG NHP 2011-2020 in response to increasing public pressure about frequent incidences of DF outbreaks and commenced in 2012 (NDOH, 2010a). DF outbreaks in Port Moresby and other major centres were reported by public health officials who linked this phenomenon to the rapidly increasing trend in rural-urban drift, unplanned urban settlements (National Statistics Office (NSO), 2006; World Bank, 2012), and the disintegration of the environment from the impact of the PNG Liquidified Natural Gas (LNG) project (NDOH; 2010b). The PNG DCP has four major program components including; (1) identification of problems (2) planning of solutions (3) implementation of solutions and (4) monitoring and evaluation of the program implementation (Figure 8).

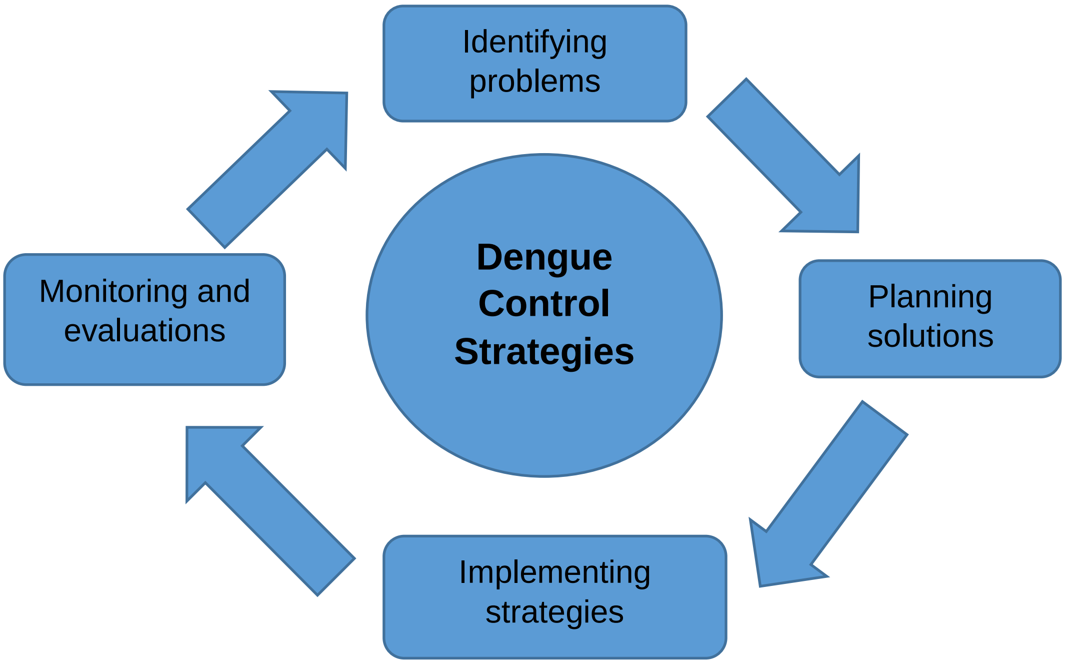


Figure 8. The Rotational PNG DCP. **Source:** The PNG NHP 2011-2020 (NDOH, 2010a).

3.2.1 Identification of issues

The capturing of the PNG DCP into the PNG NHP 2011-2020 was attributed to the identification of major issues associated with DF transmission and public health intervention for DF control and prevention. The aim was to prepare PNG public health capacity to meet the goals set in the GDS 2012-2020 to reduce the trend of DF transmission in the home environment (WHO, 2012). Both published and preliminary situational analysis reports on the PNG public health capacity by NSO (2006), NDOH (2010b) and the World Bank (2012) were used by the NHP 2011-2020 as evidence to make suggestions for optional solutions.

The first major problem identified was lack of resource allocation like what happened in the previous Malaria and Other-Vector-Borne Disease control program where focus was concentrated on malaria (NDOH, 2010b). As shown in the linear graph below (Figure 9), a bi-annual distribution of treated bed-nets over a 10-year period achieved a decline by 3.85 per 100 000 population in vector-borne disease prevalence from 10.5 in 1998 to 6.65 in 2008 (NDOH, 2010a). However, there are doubts about whether the success represented all vector borne diseases including DF given the different biting day-time hours of the *Aedes* mosquito bites compared to the Malaria vector night-time biting hours (Vanwambeke et al., 2006).

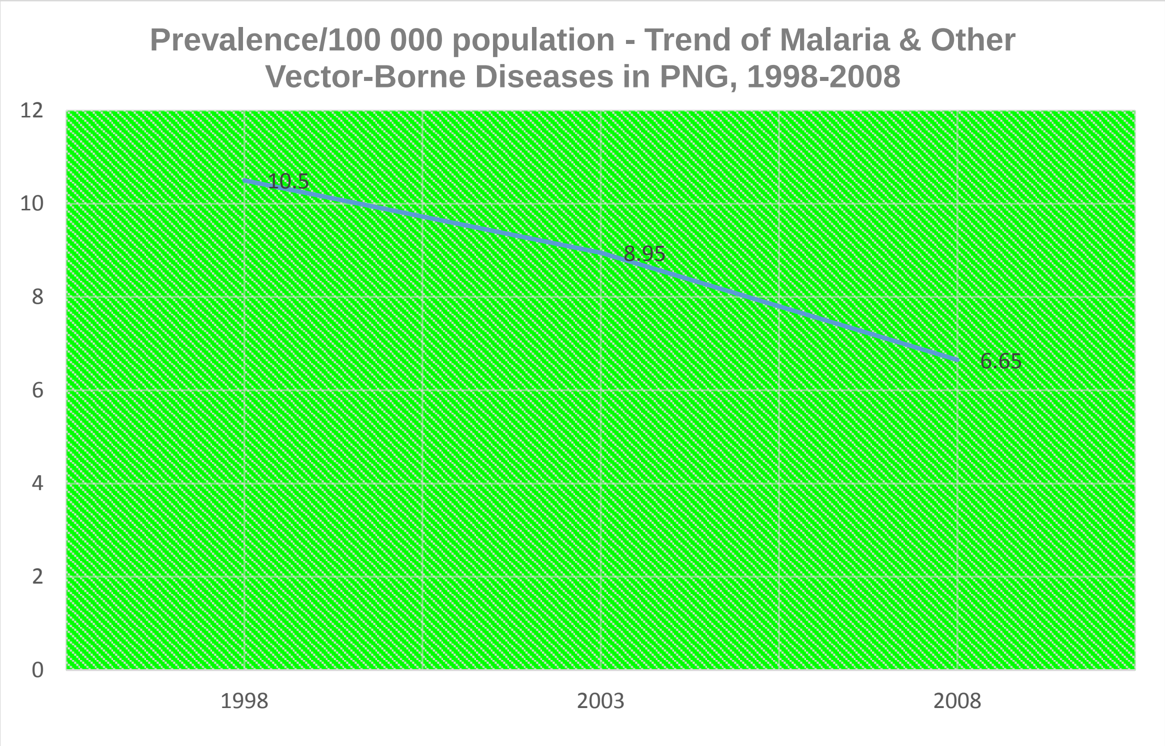


Figure 9. Linear graph showing impact of treated bed-net distribution under the Malaria and Other Vector-Borne Diseases program in PNG (1998-2008).
Source: Data from the PNG NHP 2011-2020 (NDOH, 2010a).

Kuadima et al. (2017) in their PNG-based study on the "Long-term acceptability, durability and bio-efficacy of ZeroVector® durable lining for vector control," highlighted a complete absence of an insecticides-based community vector control in PNG. The discontinuation of community-based vector control program, and the lack of focus to allocate resources for the PNG DCP, strongly indicate that DF has been neglected by the PNG public health system. This was evident with many of the communities at risk of the DF disease remaining unaware of the presence and circulation of the *Aedes* mosquito and the non-existence of a complete DF surveillance system (NDOH, 2010a).

The second major issue identified in post-implementation period of the PNG DCP continues to reflect reports by the WHO (2009b), NDOH (2010b) and World Bank (2012) that showed inadequate staff allocation and a lack of diagnostic equipment at most public health facilities in the country. With a health worker to population ratio of 1: 1333 in the PNG PHS, which is well below the global standards of 1:25 (WHO, 2009b), coping with other existing public health roll-out programs such as the TB, HIV and Malaria (bed-net distribution) may impact on the effectiveness of the roll-out of new incoming programs (Rule, Worth, Roberts & Taylor, 2012). Similarly, a lack of skilled staff and diagnostic equipment may lead to misdiagnosis and miscoding of DF, undermining an accurate data base necessary for planning the implementation of targeted DCPs.

The third major issue identified was the lack of a community-based vector control program in PNG despite overwhelming presence and circulation of the *Aedes* mosquito in both urban and rural areas (Luang-Suarkia et al., 2017: NDOH, 2010a). Although, the *Aedes* vector has been in the country since its first discovery in 1944 (Jonduo, Bande & Horwood, 2012), home-based vector reduction programs that were successful in the 1970s and 1980s have never been effectively maintained (NDOH, 2010a). Given such a situation, DF vector proliferation, breeding and circulation increases the risk of DF epidemics which can be difficult to contain under current PNG conditions.

The fourth major issue may be related to the challenges in maintaining an accurate epidemiological data-base not only necessary for estimating the total burden of DF in PNG, but also to determine targeted public health efforts (Victora, Habicht& Bryce, 2004). Lack of a DF reporting code on the daily tally sheet can lead to misreporting of potential DF cases if they are misdiagnosed as malaria or other similar febrile diseases. For instance, the sample in the study by Senn et al. (2017) may be not a true representative of PNG; the 8% (46/578) of DF cases and 14% (45/317) of negative malaria cases in Madang are significant for positive DF transmission(P=0.03), which implies an underestimated burden of DF in PNG.

The fifth major issue is the absence of a home-based DF prevention program compounded by the lack of social mobilisation and community empowerment necessary to sustain community-based DF control efforts (NDOH, 2010a). Although, many DF-risk communities in PNG were aware of the circulation of the DF vector, they continue to remain under-resourced to destroy vector breeding sites (water storage containers or old tyres) or avoid mosquito bites by use of day skin creams. In addition, the bi-annual distribution of treated bed-net distribution was often mistaken as a major strategy to prevent all vector borne diseases. Hence, with the economic burden on family budgets and the ensuing neglect of the control of DF from the home, the risk of dengue epidemics remains unpredicted.

3.3 Risk factors for DF

As Banu et al. (2011) and Ferraira (2012) have explained, biological, socio-economic, geographical, environmental and cultural factors cannot only influence home-based DF transmission, but can also impact on public health efforts for its prevention. DF outbreaks have been shown to correlate with geographical locations sustained by the increasing climatic temperatures and overcrowding, especially in uncontrolled urban settlements (Visser et al., 2011; Murray et al., 2013). Such conditions remain prevalent in PNG (NSO, 2006; World Bank, 2012), with lack of social mobilization and community empowerment through awareness. This increases the risk of DF epidemics influenced by the overwhelming circulation and breeding of the *Aedes* mosquito (Luang-Suarkia et al. 2017; Kitau et al., 2016).

3.3.1 Biological risks

Although, genetic-based disease transmission is becoming rare due to the improvement in both personal and family health and nutrition practices (Pearce et al., 2004), biological risks such as the reduction in body immunity have been implicated for facilitating disease transmission. An age-stratified analysis of gross burden of fever cases by Senn et al. (2017) in PNG found a significant proportion of DF cases in under-five year old children (p=0.03). A previous study by Anga et al. (2013) also found one in every five children in PNG was at risk of DF infection at any given time, suggesting that young age is a risk factor for DF transmission in PNG.

3.3.2 Socio-economic influences

Kinkelman (2012) has stated that, DF has a high social and economic impact that continues to increase every year and affecting not just the patients, but also their families and communities. An analysis of DF areas and its socio-economic determinants revealed that countries with higher levels of social inequality, illiteracy and populations living without access to water and sanitation services also had the highest DF prevalence (PAHO, 2014). One other socio-economic, cultural and environmental modelling case study in Delhi (India) also found that 88.2% (112/127) of suspected DF cases were reported from patients exposed to mosquito bites and living in poor housing, environments full of rubbish and other wastes (Raju & Sokhi, 2008).

Socio-economic status, education attainment and income status do not only determine DF transmission (van Benthem et al., 2002), but also impact on the possibilities of DF control within their level of knowledge (Wong, Shakir, Atefi & Abu-Baker, 2015). Individuals and families in Salvador (Brazil) having a higher socio-economic status were more likely to implement home-based vector control compared to the less advantaged (Teixeira et al., 2002). Additionally, in PNG, the daily livelihood of most people depends on subsistence farming with very little access to socio-economic opportunities (World Bank, 2012), hence lack resources to buy vector control equipment. Such disproportionate distribution of socio-economic opportunities forces rural-urban migration and the expansion of uncontrolled urban settlements (NSO, 2006), which can give rise to the risk of DF outbreaks (Teixeira et al., 2002; Torres & Castro, 2007).

Drawing from this discussion, the link between low socio-economic status and DF transmission can also determine if community-based DF control is achievable in a PNG context. Over 80% of the PNG population, of which over 40% are low in literacy, is sustained by rural-based subsistence farming (NSO, 2006; World Bank, 2012). Lacking DF knowledge as well as having limited access to vector-control equipment including day-time creams and repellents to deter *Aedes* mosquito bites during peak day-time hours becomes a risk factor for DF-risk populations. This scenario demands statutory intervention through external donor funding for low to medium income countries such as PNG (World Bank, 2012), demonstrating the need for increased advocacy and community participation, particularly when funds are not forthcoming.

3.3.3 Impact of climatic change

Climate change has been implicated as an emerging risk factor that has been a major driving force behind the expansion of DF transmission (Bi et al., 2001; Murray et al., 2013). Humid and prolonged warm weather has been found to play a significant role in adult vector survival, viral replication, and prolonged infective periods in the migration of vectors to virgin environments outside of tropical climate zones (Wilder-Smith & Gubbler, 2008). As such, the proliferation of the *Aedes* mosquito is therefore climate dependent, with changing climatic temperatures becoming a major confounding factor for global expansion of DF vectors (Murray et al., 2013).

Many studies continue to agree that there is a possibility for establishing an association between DF transmission and climate change. Based on NZDF incidence estimates, de Wet, Hales, Maindonald and Woodward (2002) predicted that, with the increasing rate of changes in climatic temperatures, 50%-60% of the global population would be living in DF risk areas by 2085 compared to less than 35% in the absence of climate change. As such, the link between humidity, temperature change and the rate of DF-borne mosquitoes heightens the risk of DF outbreaks, which is consistent with this prediction (Russel, 2009).

A PNG-based review found that, the impact of climate change on disease dynamics and the increase in the climatic temperatures provides the necessary platform for the spread and expansion of the DF vector into new geographical territories (Lang, Omena, Abdad & Ford, 2015). Although, the *Aedes aegypti* and *albopictus* mosquitoes are traditionally established in the lowland coastal PNG regions, they are slowly spreading up the mountainous regions (Luang-Suarkia et al., 2017; Lang et al., 2015). Although PNG may not have the technical capacity to reverse climate change, strong advocacy and awareness is needed to protect the environment from exploitation and destruction by logging companies. Social mobilization and advocacy in a PNG context becomes necessary to prevent unnecessary bush fires and greenhouse gasses into the atmospheric space as all contribute to the rising climatic temperatures.

3.3.4 Environmental factors

Based on recommendations from an inter-disciplinary conference on bio-diversity and health, Walther et al. (2016) explained that the exploitation and pollution of the natural environment caused by humans can influence the movement of vector from one location to another. In many developing countries, the eco-system of the natural environment has increasingly come under extreme threat of physical exploitation from agriculture, mining and large-scale logging activities (Dudley, Jeanrenaud & Sullivan, 2014). Disturbances in the environment can potentially force DF causing viruses to cross species barriers to find alternative hosts such as humans as it discovers entry and exit points for expansion (Hatcher, Dick, & Dunn, 2012).

In PNG, environmental exploitation by human activity in the name of socio-economic development has continuously threatened the eco-system and drastically distorted the composition of natural environment. Although, there is an Environment Protection Act in place in PNG (Lea, 2005), it has often been compromised through political decisions allowing the exploitation of the country's natural resources in the name of social and economic benefits. Hyndman (2001) found that the interaction between the natural environment and the health and well-being of the local communities around the OK TEDI gold mine area was severely disintegrated due to rise in uncontrolled settlements practicing unhealthy solid waste disposal practices.

In terms of geographical-based DF transmission, Senn et al. (2017) found a higher prevalence of 11% in urban areas of Madang (PNG) compared to 7% in rural areas, a shift in the trend of rural-based incidences surpassing rates incurred by urban-based transmission (Guha-Sapir & Schimmer, 2005). This finding was like the Wong et al.(2015) study in which the comparative odds of DF transmission in Malaysia was (OR=1.33; 95%CI=1.09-1.67; p=0.004) in favour of urban-based transmission. Given the increasing climatic temperature changes in the weather (Luang-Suarkia et al., 2017; Lang et al., 2015), such findings may suggest increasing changes in the magnitude of *Aedes* vector proliferation, breeding and the transmission of DF.

According to findings by Luang-Suarkia et al. (2017), the low coastal region in PNG was predicted prior to 1963 to remain a high risk geographical location for multiple vector breeding and DF transmission. However, both Lang et al. (2015) and Senn et al (2017) were critical of the increasing trend of DF transmission in semi-urbanised areas, a scenario natural to the PNG socio-economic, cultural and environmental contexts. In contrast, Senn et al. (2017) noted a change in the trend with a higher sero-prevalence in the rural areas (86%) than urban areas (76%), indicating that DF epidemic remains an unpredicted serious public health threat in both urban and rural areas in PNG.

3.3.5 Cultural influences

Cultural practices in broad terms can be referred to actions manifesting from customary beliefs about different things and events such as burial of the dead (Davies, 2017). According to the researcher’s observation and experience, one common cultural practice in PNG is the placement of drinking containers of the dead on their graves for long periods of time which allows residual water to build up. This cultural practice near family homes in PNG can influence the proliferation and breeding of DF vector and eventual transmission of DF and other vector-borne diseases.

As Spector (2002) has highlighted in his study on cultural diversity on health and illness, the many cultural beliefs in PNG can easily lead to wrong perceptions on the symptoms of DF to the work of spirits or witchcraft to justify their preference to traditional healing, thus presenting competition to western public health care practice. There are some formidable PNG cultures that are highly valued which can influence and shape community health practice at the community level as two opposing opinions exists between health practitioners and the communities they serve. As such, it can be very challenging to change the mind-set of a community member, who has been brought up through cultural nurturing, to short-term health awareness and education (Campinha-Bacote, 2002).

Therefore, some PNG cultural factors become barriers in understanding the cause of disease and its prevention, with strong ethical values and preferences which have a direct effect on disease prevention. Based on the writer's own experience, community health practitioners in PNG are often faced with challenges when introducing new health values based on modern medical and epidemiological knowledge. Although most PNG communities in recent times have been embracing on new concepts in health behaviours in disease prevention, competing values including the widespread belief in witchcraft and sorcery is causing disintegration of many communities. For instance, DF symptoms can be potentially perceived "mysterious illness" thus giving more prominence to beliefs in sorcery while, the *Aedes* vector continues to proliferate, breed and transmit DF transmission in PNG.

3.4 Public Health Interventions Post 2012 PNG DCP

The PNG WHO National Office reported 170 DF cases in Daru (Western Province) comprising of 126 clinical presentations and 44 confirmed cases, while 15 cases were reported in Port Moresby in November 2015, with no reported cases coming from other parts of the country. Of the total cases reported in Daru, 4% (7/170) developed severe forms including DHF and DSS while others were discharged. Up to 12% (21/170) of cases were reported among children under-five years of age, which was a similar finding to both studies by Anga et al. (2013) and Senn et al. (2017). The DF outbreak in the National Capital District of Port Moresby (NCD), was monitored jointly by the WHO national office, NDOH and NCD health in an effort to bring DF epidemic under control through weekly community awareness (Kitau et al., 2016).

In terms of maintaining a routine DF surveillance, suspected DF cases reported in 2016 from three electorates in the NCD were tested, not only for DF infection, but also to rule out suspicions of Chikungunya and Zika viruses (Kitau et al., 2016). Such efforts made sure blood samples of suspected DF cases have gone through rapid diagnosis testing (RDT). Blood samples were either sent to the Central Public Health Laboratory (CPHL) or the Institute of Medical Research (IMR) for confirmation. Of the total 2,555 blood samples of suspected DF cases that had an RDT investigation, 24.1% (615) of them were positive for DF with no reported deaths (Kitau et al., 2016).

Public health interventions in and around the NCD area continue to show a sign of success and improvement in controlling the 2016 DF epidemic through an inter-sectoral effort supervised by the NCD health division (Kitau et al., 2016). Targeted interventions include, but are not limited to, mass screening and testing, follow-up screening for suspected cases and contact tracing including appropriate advice. As recommended by the WHO (2009b), routine DF control activities such as the insecticide household-based spraying, fogging, cleaning and drainage were implemented, including community awareness.

Although partnerships were established between NCDC, NCD health, IMR, CPHL, WHO and NDOH (Kitau et al., 2016), there were critical issues including social mobilization and empowering communities to take ownership of home-based DF in urban settlements and rural communities. Under the current state of the PNG PHS, the lack of DF response capacity included community-based awareness about risk factors and the importance of vector control efforts (NDOH, 2010a; 2010b; Kitau et al., 2016). Thus, there is a need to expand the roll-out of the epidemiological surveillance necessary for targeted community-based DF prevention programs which can be sustained through community empowerment.

3.4.1 Issues in planning and implementing interventions

The major issue is the lack of political will to endorse the adoption and establishment of the 2010 APSED or other comprehensive vector control strategies such as the Integrated Vector Management (IVM) and the Health Belief Model (HBM). These models can become frameworks to serve as road-maps to meet the goal of the 2005 IHRs in establishing cost-effective vector control programs to control disease transmission. This shows that the current PNG DCP will continue to face capacity issues if the government continues to give less priority to build capacity for maximum DF control in PNG.

As part of the revitalization of planning process, Kitau et al. (2016) identified key areas such as capacity building especially recruiting or training technical staff in DF epidemiology, diagnosis, surveillance and vector control. This finding is consistent with the World Bank (2012) Country Report showing a gross lack of capacity in the PNG public health system to meet the demand of an increasing population for health care. Given the lack of key capacity components in the PNG DCP, its implementation since 2012 has yet to reach the more than 85% of PNG's population living in rural communities (NSO, 2006), especially in relation to DF surveillance and community awareness.

The study on the challenges in dengue control in PNG by Kitau et al. (2016) was critical of the lack of reliable DF epidemiological evidence as a basis for targeted intervention and other public health practice. Although, there is a policy directive in force to implement DF control in PNG (NDOH, 2010a), necessary epidemiological evidence was lacking with the program implementation remaining unpredictable. This situation indicates that a reliable surveillance data becomes necessary for informed evidence-based public health practice including targeted planning and mobilizing and building resources capacity.

One significant issue identified was the lack of shared responsibility between different stakeholders to defeat any potential threat from DF control to expand into new geographical areas (Kitau et al., 2016). This was evident with lack of operational research or an up-to-date evaluation by the WHO country office, IMR or from respective Provincial Health Authorities (PHAs) to identify and improve lack of skilled staff, poor DF surveillance including social mobilization, community empowerment and participation. As such, a working partnership among different stakeholders is necessary to build capacity of the PNG DCP for effective roll-out to rural communities.

Another key issue identified is the significant discrepancy in the lack of DF case registration, reporting and monthly monitoring within the PNG PHIS (NDOH, 2001), hence becoming an incompetent DF surveillance system. Both Kitau et al. (2016) and Senn et al. (2017) were concerned that the results of individual or independent studies and reports from hospitals that have access to diagnostic facilities continue to demonstrate an under-represented burden of DF in PNG. For instance, the 6-10% prevalence established by Senn et al. (2017) from a sample of 578 subjects in a single location (Madang), although a significant outcome, could be one example of a study lacking a true 95% confidence interval (CI) of PNG DF prevalence.

The evaluation and monitoring aspect of the PNG DCP, including target planning for community awareness or vector control cannot function if DF is yet to be accorded a disease specific monthly reporting code as a single disease within the PHIS (Senn et al., 2016). The absence of DF diagnostic laboratory equipment at most health facilities and lack of skilled staff are contributing factors impacting on evaluation and monitoring efforts (Kitau et al., 2016; Senn et al., 2017). Such overwhelming evidence indicates the need to prioritise resources, not only for establishing a DF surveillance system, but also for operational research to identify gaps in the practice policies and to improve implementation to achieve the anticipated goals promoted by the PNG NHP 2011-2020and GDS 2012-2020.

3.5 Summary

The PNG DCP has been evaluated with special focus on the socio-economic, environmental and cultural conditions not only as risk factors but also as determinants of successful DF prevention. The aim of the review was to evaluate the PNG DCP and establish gaps in the practice policies to influence change in the existing public health policies for DF control and prevention. The much-needed epidemiological data, an important factor in evidence-based planning and implementation of any public health program including the PNG DCP was significantly lacking.

The PNG DCP begun in 2012 as a policy directive under the PNG NHP 2011-2010 to commence as an individual disease control program away from its affiliation to Malaria and Other Vector Borne Diseases program. The program has four rotational components; (1) identifying problems, (2) planning solutions, (3) implementing solutions, and (4) monitoring and evaluation. Major issues identified in the implementation of the PNG DCP included, but not limited to:

1. Political inability of the PNG government and the NDOH to implement comprehensive vector control strategies such as the 2010 APSED strategy, IVM or HBM to serve as road-maps to achieve 2005 IHRs.

2. Lack of skilled staff and diagnostic equipment at facility level with many medical staff remaining clinically incompetent to diagnose or distinguish between DF and other febrile diseases. Misdiagnosing and miscoding of DF, DHF and DSS can lead to poor stratification or quantification of data and rendering an unreliable DF epidemiology and can lead to poor planning and implementation of DF control measures.

3. Lack of resource allocation for the PNG DCP, the closure of more than 300 facilities in rural communities where 85% of PNG population live, and a very low PNG health worker to population ratio of 1: 13,333 compared to standard WHO ratio of 1:25 were significant issues.

4. Lack of political will to build transport infrastructure in roads, airstrips, and jetties for rolling out public health program to rural areas.

5. Cultural beliefs and low levels of literacy were believed to be widespread in PNG, which also led to the lack of sustaining DF control measures in the community, particularly in rural areas.

The Government through its PHS has done very little to expand the PNG DCP beyond the scope of the established Malaria and Other Vector-Borne Diseases. There was widespread lack of resource mobilization including the prioritization to up skill staff, or to increase and expand diagnostic facilities, which led to the poor implementation of the PNG DCP that has started in 2012. In terms of community-based DF prevention, prompt attention was found to be also lacking in social mobilization and community awareness to schools, market places and villages about the importance of eliminating productive sites for mosquito breeding.

Chapter Four: Literature Review 2. Review of Innovative Vector Control Methods

4.1 Introduction

The aim of this chapter is to critically review and recommend appropriate Innovative Vector Control methods (IVCMs) that were either trialled, piloted or implemented in other DF endemic countries for implementation in PNG. IVCMs are improved, innovative or creative insecticide-based and non-insecticide-based methods using new ideas for improving control of DF and other vector-borne diseases (Hemingway et al., 2006). For instance, chemical-based IVCMs are repurposed or reformed in chemical compositions of insecticides to achieve maximum vector control, effective elimination or destruction of adult vectors, or disrupting larval vector population from productive breeding sites (Banken & WHO, 2001; Khaleghian & Gupta, 2005; Batterman et al., 2009). IVCMs also go beyond the scope of existing practice to create platforms for social mobilisation and community empowerment (Hemingway et al., 2006; Parks & Lloyd, 2004).

The overwhelming volume of literature on DF (Umareddy et al., 2007), including WHO policy directives and established evidence from intervention studies were used to appraise effectiveness and feasibility of each IVCM that was either trialled, piloted or implemented in DF endemic countries. Based on the explanation by Grant and Booth (2009), a sub-thematic analysis process was used for reviewing each IVCM not only for comparisons, but also to provide theoretical evidence if they were practically feasible in a PNG context. As highlighted by Craig et al. (2008), by undertaking a thematic analysis of the IVCMs, may allow better understanding for policy makers and public health practitioners to decide upon more appropriate IVCMs to the PNG context.

Under the theme, "using innovative methods to improve dengue control in PNG," the following sub-themes have been outlined to feature in the literature review to identify appropriate IVCMs for implementation in a PNG context.

I. Innovative repurposing (improving) insecticides
II. Innovative health communication using the HBM to address socio-cultural issues in DF transmission and prevention.
III. Innovative inter-sectoral participation (with a special focus to address socio-economic, environmental and cultural issues)

As explained by Booth, Sutton and Papaioannou (2016) and Grant and Booth (2009), a thematic analysis will not only go beyond routine descriptions of each IVCM, but will demonstrate the value of the research. Using the example of Bruce and Fries (2003), the following supplementary questions were outlined as guides to influence the examination of the potential and feasibility of each innovative method.

1. What is the definition and purpose of the theme in this review?
2. What are the advantages and disadvantages of this theme?
3. Is the IVCM an appropriate theme to pursue for implementation in a PNG socio-economic, cultural and environmental context?
4. What is the researcher's view?

By asking such investigative questions, new insight understanding can be established about the existing issues and new opportunities are created for the investigator to identify factors which are influencing DF transmission and suggest solutions to address them. For instance, considering the impact of socio-economic, environmental and cultural factors in both DF transmission and prevention, the investigator can establish an understanding of how their influence can be reduced. This will then enable the investigator the opportunity to provide suggestions to policy makers and practitioners to pursue appropriate intervention strategies that are both flexible and feasible within the socio-economic, environmental and cultural context of PNG.

4.2 Use of repurposed (improved) insecticides

The innovative idea to repurpose or improve insecticide is a new strategy featured under the IVCC model to recompose chemical strengths of each insecticide to address concerns about chemical contamination to the natural environment (Hemingway et al., 2006; Stauffer, 2013). The IVCC model is an advanced by-product of a partnership which has been created to formulate safe ready-made chemical compositions in insecticides for rapid destruction of vector populations and to reduce disease transmission (Mack et al., 2008). Hence, the repurposing of an insecticide is one example of the many IVCMs created for improving vector control and DF prevention with minimum risk of chemical contamination to the natural environment from insecticide spraying.

The aim of the IVCC model according to Hemingway et al. (2006), is to achieve two distinct objectives which are now being reinforced as a better strategy by the third (3/5) GDS 2012-2020 technical element (WHO, 2012). The first objective was not only to create research spaces for identifying different ways of creating more cost-effective and environmental friendly pesticides in their safest chemical formulations, but also to comply with socio-economic expectations (Najera, Zaim & WHO, 2003). The second objective was for every DF reporting country to have in place an effective insecticide monitoring system for evidence-based decision-making to sustain the ridding of productive mosquito breeding grounds (Hemingway et al., 2006).

Hemingway et al. (2006) further highlighted the purpose of introducing the IVCC model was based on the concept of understanding the lack of effective sustainability of the mainstream insecticide-based vector control and the prevention of vector-borne diseases in the home environment. Such a concept has led to the understanding that the lack of sustaining mainstream vector control programs was not only due to the loss of commercial public health expertise in agro-chemical industry, which had led to a decreased access to public health insecticides markets (Horrigan et al., 2002), but was also due to the increased concerns of the threat to the natural environment from spraying poisonous insecticides (Wilson & Tisdell, 2001). This scenario may indicate a significant opportunity for the re-emergence of vector-borne diseases and their expansion into new geographical areas exaggerated by the current trend in climate change (Lashley & Durham, 2007).

An IVCC is an advanced model that can provide solutions to address the restrictions placed on the purchase and use of potential insecticides used in fogging to be used only during epidemics because of the fear of contaminating the environment (Vanessa & Matthias, 2012). Traditionally, a suitable insecticide and kerosene oil were mixed for fogging application as a mainstay vector reduction strategy for massive and rapid destruction of adult vector populations in both indoor and outdoor home environments (Najera et al., 2003). As such, an IVCC model will not only address the lack of effective sustainability of mainstream vector control programs, but also offer policy alternatives to overcome the social complex nature involved in the spread and prevention of vector-borne diseases in the home environment (Hemingway et al., 2006).

4.2.1 Are repurposed (improved) insecticides feasible under the current PNG conditions?

Of the four important factors, the first factor taken into consideration is their sustainability of their implementation and whether the IVCC model will be feasible under the current PNG socio-economic, cultural and environmental contexts. Being a tropical country experiencing high burden of DF (Kitau et al., 2016; Senn et al., 2017; Anga et al., 2013), PNG will require a full-fledged DF surveillance system not only to respond adequately to epidemics, but also to sustain incoming IVCMs. Thus, despite two distinct objectives set out in the IVCC model (Hemingway et al., 2006) being consistent with the GDS 2012-2020 goals (WHO, 2012); the current PNG conditions including poor DF surveillance system may render implementation of insecticide-based IVCM in PNG unsustainable.

The second factor may be related to political inconvenience and lack of an obligatory criterion for insecticide-based IVCM in place, which might lead to difficulty in the initiation of a Public Private Partnership (PPP) proposal to implement the IVCC model (NDOH, 2010a). Despite being one of the recommended models for low-medium income countries (WHO, 2008a), the IVCC model may unlikely link up well with the already depleted PNG PHS (World Bank, 2012; NDOH, 2010b), including the absence of a full-fledged DCP (NDOH, 2010a; Kitau et al., 2017). Given the recent initiation of the PNG DCP in 2012 following policy directive of the NHP 2011-2020, and its immaturity in terms of response capacity (Kitau et al, 2016), it may be difficult to substantiate operational evidence necessary to facilitate the IVCC model in the absence of a DF surveillance system.

Third, although the IVCC concept is in harmony with the promotion of using ready-made environmental friendly insecticides (Stoddard et al., 2013), using the experiences in Thailand and Philippines, the current socio-economic situation in PNG may be less likely to guarantee the sustainability of the IVCC model in the medium to long term. For instance, respective studies by van Benthem et al. (2002) and Yboa and Labrague (2013) found that socio-economic status and demographic characteristics had significant impact on DF control and prevention efforts. PNG's low socio-economic status and human behaviour (NSO, 2006; World Bank, 2012) may not only impact on the DF preventive efforts but may be unsustainable at both family and community levels going forward.

Fourth, the long years of negligence including the lack of routine surveillance (Anga et al., 2013; Kitau et al., 2016) has resulted in many PNG communities remaining unaware of the presence and circulation of the DF vector (Luang-Suarkia et al., 2017; Senn et al., 2017). The PNG PHS would be less likely to implement the IVCC model because many communities and families in PNG have very little access to information about DF prevention (Senn et al., 2017). Such a scenario may indicate that the IVCC model may not be an appropriate strategy for implementation at this point in time under current PNG conditions where the majority of population lack accesses to socio-economic and health care opportunities which may impact on their ability to effectively sustain chemical-based IVCMs.

An IVCC model can be considered a long-term intervention for implementation to improve DF control in PNG only through a PPP arrangement (WHO, 2008b), and only when the PNG DCP is fully established to guarantee medium to long-term sustainability at the community level. Despite the IVCC model having the potential to effectively monitor the use of environmental friendly insecticides; its consistency could become short-lived given the lack of DF monitoring system in the PNG PHS (Kitau et al., 2016; NDOH, 2010a). Despite being highly complimented by WHO (2008b), the IVCC model may not be feasible or sustainable in a low-middle income country like PNG, lacking an active DF surveillance system, to facilitate an advanced IVCC model.

4.3The HBM-based Community DF education

A HBM is a concept-based health theory constructed for improving health behaviour through perceiving disease seriousness, susceptibility, benefits and barriers associated with DF prevention (Lennon, 2005). A HBM can also become the basis for influencing change in health behaviour necessary for improving community-based DF prevention education through general awareness about the disease, mosquitoes, breeding sites and routes of transmission, and its prevention (Lozano-Fuentes et al., 2012; Parks & Lloyd, 2004). An HBM concept can be promoted to enhance change in personal beliefs and cultural opinions in encouraging health promoting behaviours necessary for reducing DF transmission in the homes (Lennon &Combs, 2005). See Figure 2.

Lennon (2005) explained perceived susceptibility as a person's belief about contracting a disease, while perceived severity is the belief about the seriousness or potential consequences from contracting the disease, both giving rise to health threat. In comparison, perceived benefits, according to Lennon and Combs (2005), refer to an individual's beliefs in the value of adhering to the health-related measures for preventing disease transmission, while perceived barriers include psychologically constructed costs or other cultural values that might limit health promoting activities. Hence, the utilization of the health behaviour theory through a HBM-based DF education does not only addresses limitations in health practice behaviour (Lennon, 2005), but also influences and instils greater perceived benefits in individuals and families as weapons for disease control (Lozano-Fuentes et al. (2012).

Table 2. HBM constructs and DF messages

HBM constructs	**Dengue issue related to HBM constructs**	**Message examples to address construct issues**
Perceived susceptibility	Belief that one most likely will not contract DF	So, you don't think that DF is a real problem. DF vector can lay eggs in water drinking containers left on the grave yard.
Perceived severity	Belief that dengue is not a serious health problem	DF can be a killer. To help prevent it, any containers that could store water are removed
Perceived barriers	Not enough time to get organized for environmental clean-up	Community must also know why it is important to remove drinking containers left over graves of dead persons.
Perceived benefits	One's belief whether regular environmental clean-up will benefit to reduce number *Aedes* vectors in their homes, which in turn will reduce the risk of DF	If everyone spends just a few minutes each week to clean-up stagnant water, remove used containers from homes including cemeteries to reduce DF transmission

Note. *Based on Lennon (2005, p. 218).*

The construct of self-efficacy is one's confidence to perform the health promoting, disease prevention, and health practice behaviours using a goal orientated step-by-step approach (Lennon, 2005). The self-efficacy construct is derived from the social learning/social cognitive theory, first proposed and included in the HBM (Lennon, 2005), which can be applied in DF control using a step-by-step approach to gain confidence to perform this weekly cleaning of the home environment. For instance, teaching community members about home-based DF prevention such as rubbish disposal and removal of used containers, cans, tyres and to allow them to perform weekly under supervision over a period to gain confidence to sustain DF prevention practices.

Based on Table 2, the construct of cues-to-action can be any activity or awareness that aims to inspire, trigger, heighten or arouses interest to perform certain DF prevention practices or control epidemics (Lennon, 2005). For instance, the "cue" could take the form of a message on a poster, calendar, placards, vehicles or a message reminder through the radio network, as using media for health education can be powerful (Lennon, 2005). Such convenient and cost-effective strategy to increase awareness about the presence and the circulation of DF vectors and productive breeding sites in the home environment can sustain DF prevention and control in PNG.

A bi-product of HBM is health communication viewed by Freimuth, Linnan and Potter (2000) as the use of variety of message strategies to inform or influence individual and community decisions that enhance healthy living. An effective communication does not only feature basic principles such as being clear, simple, or positive, but also can be emotional or arouse fear about the socio-cultural influences that impact on the *Aedes* vector breeding and DF transmission. As pointed out by Lozano-Fuentes et al. (2012), the HBM does not only promote the creation of opportunities for increasing public awareness about DF prevention, but also provides opportunities for advocating changes in practice policies to address strong cultural views about disease transmission.

4.3.1 HBM-based study examples

A qualitative study based on the HBM was undertaken by Wong et al. (2013) using focus group discussions (FGDs) to establish understanding of DF transmission and prevention among Malaysian citizens living in a DF endemic region. The study found that DF awareness in the area was a regular routine community activity, however most participants demonstrated little to no knowledge about DF, DHF and DSS. Some personal (cultural) beliefs about traditional healing of DF were demonstrated in the discussions not only as potential barriers to self-efficacy, but also represented a lack of concerted home-based DF prevention efforts by study participants.

An evaluation involving a cross-section of school children and their parents occurred in Peurto Rico on the impact of being exposed to DF knowledge, prevention behaviour and residential mosquito infestations (Wince et al., 2002). The outcome showed more than 50% (399/799) of the participants (children and parents) exposed to DF education and mosquito posters and breeding sites demonstrated increased knowledge about DF transmission and prevention. Two Asian-based studies by van Benthem et al. (2002) and Chandren, Wong & AbuBakar (2015), although undertaken using different sample sizes in a different region, found correspondingly similar outcomes which imply that health education on DF is key to its prevention.

A HBM-based study (Yboa & Labrage, 2013) found that the level of DF knowledge, perceived susceptibility and perceived mosquito density in the neighbourhood correlated well with increased DF prevention practices. A similar study in India by Raju & Sokhi (2008) found that DF knowledge and prevention practices were found to be determined by socio-cultural and demographic factors including age, sex, occupation and geographical location. Such variations may not only indicate disproportionate access to socio-economic opportunities such as education and employment, but may also suggest the presence of opposing cultural views, which shows the potential for targeted HBM-based DF education.

4.3.2 Is HBM-based DF Education an appropriate IVCM to Improve DF control in PNG?

According to Glanz and Bishop (2010), HBM raises the need for health education and promotes disease prevention practices through community-based education and awareness to force change in health behaviour using socio-cultural networks. A HBM becomes an important strategy to improve awareness about the presence and the transmission of diseases and empowers community members to take ownership of disease prevention. As such, the HBM is also known as the health behaviour theory (Lennon, 2005) and can be utilised in PNG to provide explanations about *Aedes* mosquitoes, their breeding sites, including water drinking containers, tyres, cans and flower pots (WHO, 2012).

As Lennon (2005) has explained, the principle constructs of the HBM framework creates clues to action and self-efficacy used for designing community-based health education intervention for positive change in health behaviour. With most of the population in PNG living on subsistence farming (World Bank, 2012; NSO, 2006), the HBM becomes an appropriate strategy to empower community with DF knowledge to influence change in health behaviour. Community-based health networks including, but not limited to health centres and village aid-posts, schools, markets and church grounds, can be used effectively to impart DF education and awareness to improve DF prevention and control in PNG by eliminating productive vector breeding sites and community cleanliness. As such, this model can be used in conjunction with the inter-sectoral model discussed in the next section.

According to Eisen, Beaty, Morrison and Scott (2009), implementing public health intervention programs aimed at eliminating vector sources from home environments using insecticides to disrupt vector-borne disease transmission were often based on ineffective practice guidelines. PNG socio-cultural conditions may become more receptive to HBM-based DF education and awareness as the safest, simple and an affordable DF prevention strategy, rather than rolling out insecticide-based vector control strategies that might become unsustainable in a PNG context. Improving community-based DF prevention and control can be achieved by the HBM not only with an aim to increase perceived disease seriousness, susceptibility, and barriers (Lennon, 2005), but also to improve health behaviour to prevent the proliferation of *Aedes* vectors, productive larval breeding sites and disease transmission (Glanz & Bishop, 2010).

The PNG PHS, while focussing on establishing a strong DF response program including a rapid surveillance system necessary for an up-to-date adjustment to target interventions should have greater focus on community awareness as a priority. DF education can be rolled out to the communities using the established PHS delivery systems and community networks including local level governments, village councillors, churches, women and youth groups. Such a method will not only increase community perceptions about DF, but will build partnerships with communities to take ownership of cost effective vector control methods. For example, mobilising the community for home-based rubbish disposal and removing potential vector breeding sites (empty drinking containers, old tyres or tins) from the home environments links up well with the next section on inter-sectoral approach for DF control.

4.4 An Inter-Sectoral Stakeholder Participation

According to Parks and Lloyd (2004), a participatory or inter-sectoral approach is one other of the innovative intervention methods aimed at achieving maximum DF control and prevention through active involvement of different stakeholders, social mobilization and community empowerment. The three interventional studies that were undertaken to evaluate the effectiveness of a participatory approach in LA provided some insights into the importance of involving different stakeholders in DF control (Sommerfeld & Kroeger, 2015; Michel-Foster et al., 2015; Caprara et al., 2015). The findings showed significant reductions in both adult and immature vector populations after introducing innovative participation to involve and empower public health workers, schools (teachers, students and parents), and line managers and host communities.

A community-based innovative vector control intervention study by Sommerfeld and Kroeger (2015) was undertaken to test the effectiveness of a multi-disciplinary approach to gain evidence across LA for improving DF and Chagas disease prevention in both urban and semi-urban socio-ecological settings. Significant reductions in vector densities were achieved among participating communities involved in garbage collections as compared to those communities that depended on routine public-sector efforts - highlighting the importance of social mobilisation and empowerment (Parks & Lloyd, 2004). Social mobilisation and empowerment can be replicated as an innovative vector control strategy to improve DF prevention in PNG, a country experiencing challenges in socio-economic opportunities, high rural-urban migration, uncontrolled urban settlements, increasing population growth and social overcrowding (World Bank, 2012; NSO, 2006).

A similar study was undertaken by Michel-Foster et al. (2015) to evaluate the impact of an Integrated Intervention Strategy (IIS) on the eco-bio-social scaling up of local success in entomological intervention through social mobilisation in Machala (Ecuador). This innovative IIS involved participant clusters, while the existing DF programs were used as control clusters with pupae per index (PPI) used as an outcome measure. The overall outcome of this innovative intervention was a success with overwhelming reductions in the PPI levels as compared to control clusters (Michel-Foster et al., 2015). This is despite the argument that, individual cases were more likely to demonstrate the need for contextualized interventions (Braks et al., 2014).

Another intervention study by Caprara et al. (2015) in Fortaleza (Brazil) evaluated the impact and of social mobilization and community empowerment as an innovative approach to DF control. The study included ten clusters in the intervention and ten in the control group for comparing the effectiveness of community workshops, clean-up campaigns, non-larviciding efforts including the covering of elevated containers and rubbish disposal and mobilization of school children for the distribution of Information, Education and Awareness

(IEA) materials. There were significant differences demonstrated in the levels of social participation, commitment and leadership, thus indicating the relevance and feasibility of such participatory approaches for DF control in PNG socio-economic contexts.

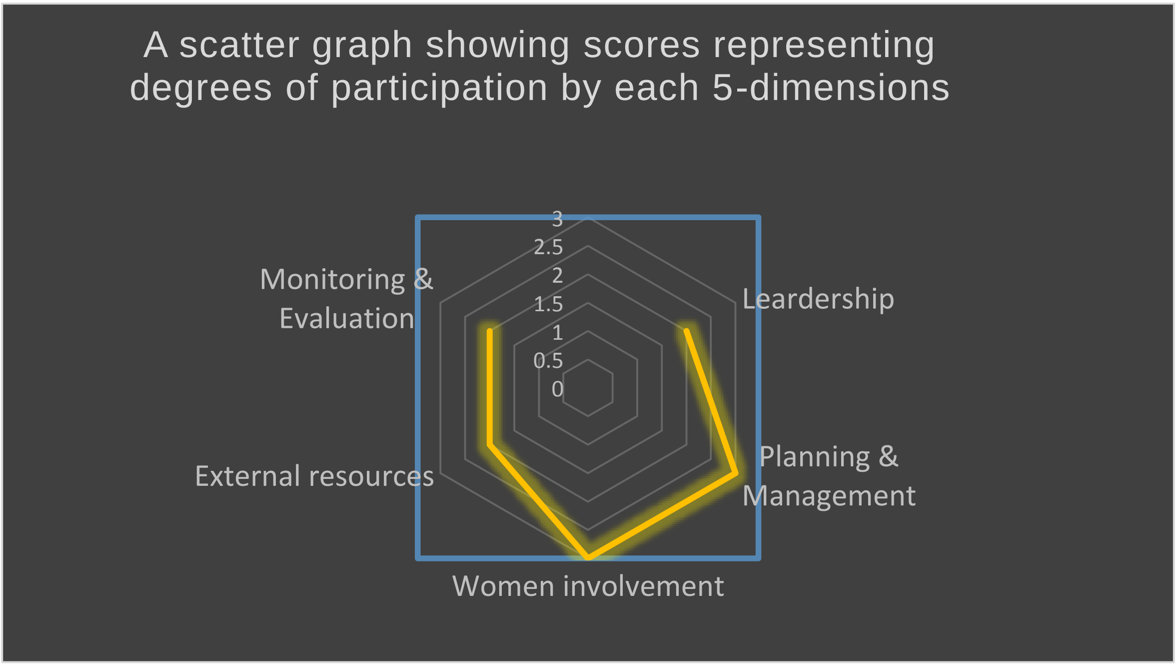
4.4.1 A participatory approach to empower communities

According to Suarez, Olarte, Ana and Gonzalez (2005), cultural, socio-economic and environmental factors not only are common dependent variables in the causation and transmission of disease, but also influence disease control and prevention. According to Ferreira (2012), DF transmission is associated with the lack of socio-economic opportunities such as lack of education and employment not only in knowing about DF transmission around the homes by Vectors, but also the purchasing power to access vector control equipment. As highlighted by Raju and Sokhi (2008), the promotion of a participatory approach in PNG is an innovative idea to address issues associated with socio-economic, environmental, and cultural factors to improve DF control at the community level (Raju & Sokhi, 2008).

A cross-disciplinary research by Finkelman et al. (2014) evaluated the level of risk of ecological, biological and social factors in DF vector breeding and transmission in low-middle income countries in LA. It was found that, more than 50% of global population were living in DF risk regions, the impact of the higher levels of inequality in socio-economic and literacy had led to poor sanitation and water services and high incidences of DF were reported by families and communities. Similar revelations were established by Basso et al. (2015) in Salto (Uruguay) which showed correlations between geographical, socio-economic and cultural factors and DF transmission. This may indicate the need for cost-effective participatory approaches to improve DF prevention in PNG, a low-middle income country.

As proposed by Draper, Hewitt & Rifkin (2010), a process indicator framework was used to develop a platform for assessing community participation in health programs to evaluate the effectiveness of inter-sectoral participation. Basso et al. (2015) found that the voice and contribution of women had the greatest impact in influencing decision-making compared to four other key performance indicators of leadership, planning and management, external resources support and monitoring (Figure 10). Such a participatory approach therefore demonstrates the potential to address socio-economic, cultural, geo-demographic and environmental issues associated with DF transmission (Parham et al., 2015; Raju & Sokhi, 2008) and control through social mobilisation and empowerment.

Figure 10. Scatter graph illustrating scores on a 1-5 scale based the degree of participation and intensity of self-assigned scores.



Note. Based on data from Basso et al. (2015)

From the cost analysis, it was determined that such an innovative intervention implemented in Uruguay saved costs by more than 20% (6.93/8.82-1) per household-based intervention compared to routine DF control. It was also noted that an intervention featuring a participatory approach involving community members in home-based DF prevention that includes rubbish disposal and removal of empty water holding containers showed lower costs than routine activities by 55% (2.98/6.65-1). The result showed that the saving of costs in the intervention in Uruguay can be generalized and replicated in other similar socio-economic and cultural settings like the PNG context to improve DF prevention and control.

4.4.2 Is an Inter-Sectoral approach appropriate for PNG?

An inter-sectoral approach involving different stakeholders including state authorities, public health workers, teachers and students, community members, especially women and youths, may be a cost-effective strategy in PNG. This strategy highlighted by Sommerfeld and Kroeger (2015) was effective in both Mexico and Columbia; however, it was an integrated effort comprising not only of the chemical-based, but also of non-chemical-based methods (Quintero et al., 2015; Che-Mendoza, 2015). While chemical-based methods such as treated curtains, window and door screens would not be effectively implemented in a PHS lacking an existing DF program, non-chemical-based methods such as the removal of productive vector breeding sites, rubbish disposal and distribution of IEA materials in community can successfully reduce vector populations.

The IIS should be considered as one of the best community-based approaches for DF prevention in a DF endemic country like PNG, in conjunction with insecticide-based methods. By implementing the IIS in PNG, greater reductions in mosquito densities, especially the PPI can be achieved, not only through social mobilization and empowerment but, by linking up well with existing public health programs. Although more accurate assessment of the general socio-economic status of PNG citizens is necessary for sustaining the IIS, the poor health and socio-economic indicators in PNG (NSO, 2006; World Bank, 2012) warrants the need for such comprehensive approaches.

As Caprara et al. (2015) has suggested, the implementation of the IIS in PNG can be effective if there is an increased level of social participation, commitment and leadership from different stakeholders which is consistently maintained. Although, the chances of the IIS acceptance, feasibility and sustainability in a PNG context remains low, based on Huthmaker (2015), empowering community members including youths and school children in general rubbish disposal campaigns or distribution of IEA materials can potentially increase and enhance DF prevention. Implementing such a participatory approach in PNG through social mobilization can encourage community members to overcome cultural views about disease causation and take ownership of the responsibilities required in keeping their home environments free of productive vector breeding sites.

With most PNG population sustaining their living on subsistence farming in rural areas with little access to socio-economic, literacy and health care opportunities (NSO, 2006),it is also important to understand that, there is evidence of circulation of the *Aedes* mosquitoes throughout PNG including the rural areas (Luang-Suarkia et al., 2017; Jonduo et al., 2012). As such, a participatory approach becomes necessary in PNG as a step forward strategy, not only to mobilise and empower community members (Parks & Lloyd, 2004), but also to arouse or trigger interest and commitment among other key stakeholders such as the public health officials and line managers.

4.5 Summary

A set of supplementary questions such as those used by Bruce and Fries (2003) in the Stanford Health Assessment Questionnaire were applied to evaluate effectiveness of the implementation of the IVCMs. The review evaluated different IVMCs that were trialled, piloted or implemented in other DF endemic countries and discussed in specific themes. These themes included the use of improved insecticides, HBM-based community DF education, and participatory innovative methods with a focus on addressing socio-economic, cultural and environmental issues through community empowerment.

Not all IVCMs were found to be effective in all socio-economic, cultural and environmental contexts except for those which featured non-chemical-based or integrated IVCM applications. Hence, chemical-based IVCMs such as those found in the IVCC model were only effective under well-established DF control programs and effective diseases surveillance systems. As such, implementation of the IVCC-based methods under the current PNG PHS conditions may not be feasible in terms of effective evaluation and sustainability at the community level.

Implementing a community-wide HBM-based DF education can be a cost-effective IVCM to improve control DF transmission in low-middle income countries like PNG having low socio-economic indicators, unhealthy home environments and cultural challenges. A HBM features a health behaviour theory and sets the framework necessary for increasing awareness about disease susceptibility, disease severity, barriers, and benefits and self-efficacy for DF prevention. By implementing the innovative HBM-based community education in PNG, communities will be educated about *Aedes* mosquitoes and their breeding sites including empty containers, tyres, cans and flower pots and the importance of ridding them from homes and public places.

A participatory approach with the involvement of different stakeholders including community members (schools, youths), public health officials and program managers can be an effective approach in PNG. An inter-sectoral participatory approach becomes an appropriate DF prevention strategy in PNG to advocate and empower community members to take ownership through social mobilisation as well as to contribute to productive decision-making as agents for change and the representative voice for the community.

Chapter Five: Discussions and recommendations

5.1 DF summary

DF is an old infectious vector-borne disease transmitted by the Aedes mosquito, first identified as "poison water" linked to "flying insects" between 265 and 420 AD during the Chin Dynasty and recorded in 992 AD in a Chinese Encyclopaedia (Gubler, 2014). The WHO recognises DF as a notifiable public health disease that is broadening its expansion and endemicity from 10 countries in the 1950s to more than 125 today (Ferreira, 2012; WHO, 2011a). Based on the background analysis, global DF endemicity and expansion has been linked to socio-economic and environmental risk factors (Lashley & Durham, 2007; Murray et al., 2013). For instance, increase in uncontrolled urbanization, overcrowded settlements and local cultural practices have been implicated as the vehicle in establishing new breeding grounds through poor rubbish disposal practices of empty containers and used tyres (Dutta & Mahanta, 2006).

Given the seriousness and the high fatality rate of severe forms (DHS and DSS) (Bhatt et al., 2013), it is necessary to identify and confirm a DF outbreak if more than two or more cases presenting similar manifestations. Based on the WHO (2009a) standard clinical and laboratory classification of DF, symptomatic-relieving home-based care including bed rest and fluids should be given for mild cases, and intravenous (IV) fluid replacement and blood transfusion for severe cases with shock from loss of excessive blood (Bhatt et al, 2013). However, it has been found that in low-middle income countries like PNG, there is lack of proper medical and diagnostic facilities for rapid serological screening, confirmation and notification of epidemics to public health authorities (WHO, 2013b; 2009b).

DF is classified under the global infectious diseases category (WHO, 2009a), however it has remained neglected disease in many DF reporting countries including PNG (Murray et al., 2013; Horstick, Tozan & Wilder-Smith, 2015). It was also noted that the shift in attention and resources allocation to the development of anti-viral drugs and DF vaccine had very little success (Guy et al., 2011; Banu et al, 2011; Murray et al., 2013).As a result, community-based vector control strategies were ineffectively sustained not only in response to increased environmental concerns raised against use of poisonous pesticides (Rose, 2001), but also due to the lack of social mobilization and empowerment (Spiegel et al., 2005).

The global expansion of climate change, modern-age, international travel, trade and urbanization have been implicated as contributing factors influencing the spread of the *Aedes* vector from one region to another around the world (Bi et al., 2013; Torres & Castro, 2007). The first reported epidemics in PNG were in Rabaul on the New Britain Island in 1944 and 1971 followed by a third epidemic in Wewak in 1978 on the mainland (NDOH, 2010a; Kitau et al., 2016), which triggered four regional-based entomological surveys to be undertaken between 1987 and 2008 (NDOH, 2010a). These studies, including the recent serological survey on evidence of multiple DF virus sero-types by Luang-Suarkia et al. (2017) in both PNG and West Papuan regions, confirmed overwhelming presence, circulation and distribution of the DF vector species across all regions of PNG.

A DF specific response program was only started in 2012 based on a policy directive of the PNG NHP 2011-2020 in response to wide-spread public concerns about DF outbreaks in many areas of PNG (Kitau et al., 2016). This program was designed to address issues associated with both entomological and epidemiological surveillance to improve DF data including incidence, prevalence and DF-related mortality rates necessary for targeted community-based vector control interventions that has been lacking under the Malaria and Other Vector-borne Diseases program (NDOH, 2010a). The next section discusses the effectiveness of the PNG DCP in full view of the influences of socio-economic, cultural and environmental factors.

5.1.1 The Impact of the PNG DCP

First, this review confirms that DF is not only an important public health disease that must be given priority in PNG (Senn et al, 2017), but also that socio-economic, environmental and cultural factors make this a significant challenge. It was also suspected that the trend of DF in PNG is associated with the high rate of rural-urban migration and the increase in uncontrolled settlements in towns, mining and logging sites (NSO, 2006; World Bank, 2012). In addition, many families in PNG experience lack of DF knowledge about *Aedes* vector and its breeding sites such as empty drinking containers, used tyres, tins which influence DF transmission around the homes.

Second, existing issues within the PNG DCP associated with the capacity for adequate DF control remain a challenge within the PNG PHS from achieving both target goals of the GDS 2012-2020 (WHO, 2012) and PNG NHP 2011-20 (Kitau et al., 2016). For instance, there is widespread lack of skilled staff, diagnostic laboratory facilities, external stakeholder relations, and funding (including a PPP) necessary to get the program off the ground and rolling it out to the settlements, rural districts and villages (World Bank, 2012; NDOH, 2010b). There is lack of capacity for routine DF surveillance to monitor DF-related incidence, outbreaks, prevalence and mortality, thus planning and capacity building for target intervention remains a challenge.

Third, DF continues to remain a neglected disease despite being a well-established disease in PNG since its first reported outbreak in the post WWII period (Kitau et al., 2016), and also recognized as a public health notifiable disease (WHO, 2013). In addition, a localised study has found DF to represent 8% (46/578) of all febrile cases and negative malaria cases by 14% (45/317) in Madang (PNG, with higher proportion of infections in under five children (Senn et al., 2017). This scenario suggests that, little attention has been given to DF under the existing Malaria and Other Vector-Borne Diseases program (NDOH, 2010a) including lack of public attention to protect the PNG young age group at a high-risk factor of DF infection.

Fourth, it was also found that there have rarely been major routine community-based intervention programs on DF control and prevention by the PNG PHS right down to the village level (NDOH, 2010a). Although Parks and Lloyd (2005), and Draper et al. (2010) strongly emphasized the importance of community involvement in disease prevention, there is lack of community empowerment, advocacy and social mobilization in DF prevention. As both Kitau et al. (2016) and Senn et al. (2017) have implied, most of the PNG population living in rural and semi-urban settlements may know very little about the *Aedes* vector, their breeding grounds and route of transmission.

Therefore, the PNG DCP appears to be lagging in implementation due to PHS capacity issues including, but not limited to a lack of a robust DF surveillance system necessary for target prevention interventions, lack of diagnostic and skilled staff at facilities from main centres right into rural community health posts for confirming incidence of DF infection and the absence of an inter-sectoral approach necessary for collective input for community awareness, social mobilization and empowerment. Thus, not only is there lack of DF knowledge in communities, but also because of existing unaddressed socio-economic, environmental and cultural issues, any initiation of community-based DF control in PNG is unlikely to become sustainable.

5.1.2 The review of the IVCMs

A set of themes were identified in the second critical literature review on the effectiveness of innovative vector control methods that were either implemented, trialled or piloted in some DF endemic countries. With an aim to achieve the study objectives, this review gained new understandings about the feasibility of each IVCM within the PNG cultural, socio-economic and environmental contexts. The following is the summary of the discussions undertaken on the themes on IVCMs used in the review from which new ideas were drawn on how they could be used for improving DF control in PNG.

First, the use of improved insecticides under the IVCC model including the integration of two or more insecticide-based IVCMs were found to be effective in contexts that already have access to existing DF control programs which are routinely evaluated for effectiveness(Hemingway et al., 2006).Given the lack of a full-fledged DF control program in PNG (Kitau et al., 2016), the government is yet to prioritize separate funding and other resources to fully support the implementation of the PNG DCP on a routine basis. As such, implementing an IVCC model featuring advanced systems and promoting the use of improved insecticides may face both timely evaluation and capacity challenges, making it unsustainable under current PNG conditions.

Second, the HBM-based community-based DF education theme was reviewed using literature from other DF endemic countries and found to be a very effective method that can be replicated in any context (Wong et al., 2014). For instance, using community-based groups such as youths, women and church organizations can highlight the potential as agents for change in increasing social communication to improve community perceptions about the presence and circulation of the *Aedes* mosquito in the neighbourhood (Wince et al., 2002). Although Khun and Manderson (2007) highlighted commitment to other duties as a challenge in fully engaging in practicing DF prevention practices at home, most parents whose children were exposed to DF prevention education in a study by Winch et al demonstrated interest in routine rubbish disposal and removal of vector breeding sites (2002).

A HBM-based community DF education becomes an innovative method of intervention that can be affectively applied in any socio-economic and cultural contexts (Wong et al., 2014), and challenges cultural misconceptions as well as influencing change in community perceptions about presence and circulation of the *Aedes* mosquito (Lozano-Fuentes et al., 2012). Given the lack of rolling out PNG DCP into the districts (Kitau et al., 2016; Anga et al., 2013), DF awareness becomes an immediate strategy for community-based self-sustaining DF control and prevention. This strategy can be very receptive in PNG at schools, health clinics, market places, churches including traditional social gatherings than other vector control initiatives.

The third identified theme is using participatory approaches for community-based vector control by involving different stakeholders in decision making and program implementation (Parks & Lloyd, 2004; Sommerfeld & Kroeger, 2015). Although little literature was established in the literature for women's role and participation, in one study a representative voice on their behalf was significant and greatly impact on the decision-making process among different stakeholders (Mitchel-Foster et al., 2015). Such a participatory approach can encourage productive community commitment to home-based DF control as well as empowering communities to make informed decisions based on best local knowledge (Caprara et al., 2015; Mitchel-Foster, 2015).

An inter-sectoral participation is an appropriate approach in the PNG context for the creation of opportunities for different stakeholders to contribute meaningfully to address critical issues of inequality in accessing socio-economic and education opportunities including sanitation and clean water supply (Finkelman et al., 2014). For instance, the NDOH consults with other sectors including community development, agriculture, education, and town authorities in decision-making to maximize and roll-out DF prevention activities right down to the community level. As Parks and Lloyd (2004) have explained, an inter-sectoral collaboration promotes participatory action thus creating opportunities for different stakeholders, particularly the community members to sustain home-based DF prevention measures.

Therefore, an inter-sectoral participatory approach becomes necessary in PNG because, it can also strengthen and expand the current DF program which the country has yet to get fully established. This approach can be successfully rolled out using linkages within the PNG PHS structure down to the district health centres and aid posts to link up with local schools, local level government officials, churches and the general population at the village level. Such approaches to engage community members will most likely empower them to use local knowledge among different stakeholders to contribute meaningfully to devise effective strategies that can also sustain home-based DF control in PNG.

5.2 Recommendations

Key recommendations will aim to address issues that were identified in the background situational analysis, and reviews of the PNG DCP and IVCMs implemented in other DF-reporting countries. Special consideration will be given to influences of socio-economic, cultural and environmental conditions on DF transmission and its control and the most practical policy options in the form of practice models provided by the WHO for effective control and prevention of DF. With a special focus on social mobilization, community empowerment and participation, the following practice options including IVCMs are consistent with three policy options for improving DF control in PNG with an aim to achieve the GDS 2012-2020 goals of 50% reduction in mortality and 25% in morbidity are achieved by 2020 (WHO, 2012).

5.2.1 Improving DF surveillance

A top priority of the PNG DCP is the immediate establishment of a DF surveillance system prior to the implementation of IVCMs as immediate, inter-mediate and long-term efforts as suggested by both APSED and IVM standard practice policy models (WHO, 2004; 2008b; 2011a). The key reason is that an effective DF surveillance system is necessary for the sustainability of any potential IVCM to improve DF control in PNG (WHO, 2011a). DF was responsible for 6-10% (46/578) of all febrile illness and 10-14% (45/317) of all malaria-negative cases with higher prevalence in less than five-year-old children in a few PNG studies (Senn et al., 2017). As such, a DF specific disease reporting code is needed to be captured on the health facility daily reporting tally sheet through a policy directive to improve monthly DF reporting and surveillance.

Given the importance of evidence-based public health practice (Victoria et al., 2004), a standardised surveillance system is required for target IVCM-based DF intervention planning and implementation. Knowing the true burden of DF in PNG will also provide a platform not only for creating better policies but also necessary for creating avenues for social mobilization, community empowerment and participation at community, village and family level. In addition, DF surveillance can go further in setting the basis from which special health care can be derived targeted at improving the prevention of population-based DF transmission including DF immunization coverage for children.

Given the lack of funding and prioritizing budget allocations for DF control in PNG, a bilateral arrangement between potential funders and the government could advocate for PPP funding to get a full-fledged DF control program. The aim is to get a robust DF surveillance system fully established and to strengthen capacity of national health information systems (NHIS) necessary for adequate response to DF outbreaks and other epidemics (WHO, 2011a). This would also include the early detection of DF, referral of DHF and DSS and prompt dissemination of information as part of this policy option (Bhatt et al., 2013). The donor funded DF surveillance system is important not only for identifying a potential DF outbreak in PNG, but also to monitor factors favouring its occurrence through mass or routine serological screening necessary for epidemiological data (WHO, 2009b).

It is expected that a fully-established DF surveillance system would improve DF notification for reporting any presumptive or classical DF including severe cases (DHS and DSS) at district, provincial, national levels and across international borders (WHO, 2009b). It is also mandatory that an incoming DF incidence report is received and compiled as sensitive public health information bearing the date of occurrence, number of cases, number of suspected deaths, and demographics of those affected including sex, age, and location. An epidemiological report can include either narrative reflection of disease phenomenon, a clinical intervention report, details of a DF viral isolation and or details of planned control measures as part of a well-informed contribution to global burden of DF (WHO, 2007; 2009b).

5.2.2 A HBM-based DF education

A PPP arrangement can also be considered for the immediate to long-term implementation of the HBM-based community DF education featuring perceptions about susceptibility, seriousness, benefits and barriers for influencing change in human behaviour in PNG (Lennon, 2005). Given that DF remains a neglected disease (Senn et al., 2017), and circulation of the *Aedes* vector is wide-spread in PNG (Luang-Suarlia et al., 2017), HBM-based DF education can address issues associated with lack of DF knowledge not only about transmission, mosquitoes, productive breeding sites or peak biting hours, but also about its control and prevention. The HBM-based health communication strategy becomes an immediate to long-term practice solution especially for reaching out to convince culturally diverse PNG communities to understand DF transmission around homes to change their behaviours and take ownership of DF control and preventive measures.

By implementing the HBM-based DF education, a Social Cognitive Theory (SCT) model could be used at interpersonal or interactive level (Bandura, 2011) while, the Diffusion of Innovations Theory (DIT) model could be applied at community or organizational level to influence change in practice behaviour (Dearing, 2009). Using these innovative communication methods to impart information is not only effective in changing people's perceptions about DF transmission, but effective in influencing positive changes in DF prevention practice behaviours (Wong et al., 2015). Effective delivery of behaviour changing message through these communication theories are most likely to be achieved when messages are clear, simple, positive and rationale to motivate positive changes in DF prevention behaviour (Freimuth et al., 2000).

The HBM-based SCT will focus on imparting DF education to family members, friends, co-workers to influence their health behaviour not only through personal experience but also by observing DF preventive actions undertaken by others (Bandura, 2011). Likewise, the DIT will be directed at improving or strengthening health communication channels, social networks and systems, community cultural norms and structures with new ideas and practice products using established patterns (Dearing, 2009). Given PNG's cultural diversity with its people having different perceptions about causation and transmission of DF, this policy option becomes an immediate solution and links well with the inter-sectoral participatory approach for empowering both individuals and families to overcome cultural barriers and change their behaviour to improve DF prevention.

5.2.3 An Inter-Sectoral-Participatory Approach

One immediate strategy to consider implementation as an inter-=mediate to long-term solution is the participatory DF prevention through an inter-sectoral involvement of different stakeholders based on all three (HBM, IVM and APSED) practice policy options. Given the association between DF transmission and socio-economic, cultural and environmental influences (Murray et al., 2013; Raju & Sokhi, 2008), it is imperative that participatory action to improve DF control is considered for promoting social mobilization, community empowerment (Parks & Lloyd, 2004). With PNG remaining a country with low socio-economic and poor health indicators (NSO, 2006; World Bank, 2012), an inter-sectoral participation becomes an appropriate and cost-effective approach in DF control and prevention.

As Sommerfeld and Kroeger (2015) highlighted, the aim of this practice policy is to empower community members to take ownership to contribute in decision-making and sustaining community-based DF control measures. The implementation of this policy option will also make sure each stakeholder including public health officials, program managers, donor agencies or members of host communities actively contributes to interventions that are introduced or rolled down to rural communities (Parks & Lloyd, 2004). In addition, the many sustainable interventions such as the social mobilization and community empowerment for active participation by all stakeholders encourages minimal costing and self-sustainability, especially in a PNG context with diverse communities practicing different cultural beliefs and customary traditions (Fearon, 2003).

A participatory option for non-insecticide-based IVCMs such as DF awareness and community campaigns for proper rubbish disposal and removal of productive vector breeding sites looks more promising for effective sustainability at the community level. However, insecticide-based IVCMs can also be implemented as a long-term DF control strategy through an inter-sectoral participatory approach by government to government bilateral donor arrangement such as the PPP concept. Empowering community members as important stakeholders through social mobilization and advocacy can be a powerful tool to encourage members to become “agents of change” through self-sustainable home-based vector control and DF prevention measures.

5.2.4 Strengths and limitations of study

A major strength is that, the study was able to utilize the full intentional databases in NZ to access wide range of information that might have been more different to access in a PNG. In addition, as a PNG health professional, the researcher can give insight ideas how communities can be mobilized and empowered to increase participation to improve DF control at the community level. For example, using his many years of work experience in different communities, the researcher can use community networks to develop plans based on community needs.

Limitations to this study may include but not limited to the short study time frame, study methodology including data analysis techniques including data charting tables were poor. In addition to that, accurate demographic-based DF database for age, sex and socio-economic including geographical location-based epidemiological data on incidence, prevalence and mortality rates were missing in PNG-based literature. Further, there was lack of participatory action research articles including literature coverage on the role and influence of women and other community-based groups.

5.3 Conclusion

DF is now globally recognized as an important vector-borne disease that is rapidly expanding to new geographical locations influenced by massive globalization, increased international trade and climate change. There is marked impact of the socio-economic and cultural factors not only on the transmission of DF but also having an impact on existing DF control measures in many countries including PNG to effectively contain the magnitude of DF expansion and spread. There is lack of response capacity including an effective surveillance system and skilled staff to properly quantify total DF burden in PNG. Insecticide-based IVCMs such as larviciding compared to participatory IVCMs such as HBM-based community DF education worked well in communities whose members were adequately empowered socio-economically to fully participate.

Given lack of budgetary priority for DF control and low socio-economic lifestyle in PNG, a bilateral PPP arrangement between the government of PNG and potential donor agencies such as Global Fund should be advocated for to sponsor the full implementation of both insecticide-based and non-insecticide-based IVCMs as both immediate and long-term strategies. Overall, advocacy at the global level is required to address issues associated with social justice in the socio-economic and infrastructure development in PNG. Therefore, this study recommends the following specific intervention strategies based on immediate, inter-mediate and long-term DF control approaches based on the PNG socio-economic, cultural and environmental contexts:

1. Community-based and inter-sectoral participatory IVCMs including HBM-based DF education be considered immediate to inter-mediate intervention measures to promote social mobilization and community participation for cleaning their home environments, practice proper waste disposal, ensuring safe water and sanitation to set the necessary platform tor insecticide-based IVCMs.

2. Larviciding techniques using repurposed insecticides to be implemented in the long term for comprehensive destruction of different mosquito

larval stages in the home environment after the PNG DCP fully establishes an effective DF surveillance system and when families and individuals have been socially and economically empowered to take ownership of DF control from their homes.

3. Meanwhile, an effective DF surveillance system remains a top priority necessary for enhancing on-going operational research or other interventional studies to properly quantify DF incidence, prevalence and mortality to create better practice policies for DF control in PNG.

Finally, the limitations in PNG-based literature on DF control and prevention have led to the reviewing of non-PNG based studies that were undertaken in other DF reporting countries relying on data from full-fledged running DF control programs. Although, the influence of socio-economic, cultural and environmental factors in DF transmission and its control was significant in PNG, lack of participatory studies especially the involvement of community-based women and youth groups as community advocators was worrisome. Further research for investigating issues of inequality in view of accessibility to socio-economic opportunities and DF transmission and its control will require participatory action research approaches to promote social justice and advocacy for at risk vulnerable populations including pregnant women and children, Hence, more participatory-based research is required to investigate critical issues of interest such as inequality in the distribution of socio-economic services including access to DF control services for vulnerable populations including children and pregnant mothers who are at an increased risk to DF infection.

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Appendices

Appendix A: Vocabulary of Dissertation

***Aedes aegypti* –** is one of the four female dengue vectors as a sole putative factor responsible for transmitting dengue fever in PNG**.**

***Aedes* peak biting hours** – refers to the most likely hours which are the mornings and evenings for the *Aedes* mosquito to bite an infected person and gets infected and then transmits to another healthy person.

Agro-chemical – refers to chemicals including fertilizers for improving the yields of agricultural crops and chemicals used in agricultural machinery with spill-off effects to the natural ecosystem (environment).

Dengue-based co-morbidities – refers to a serious emergency in which two or more disease conditions concurrently occurring as complications especially in the convalescent stage that has withstood clinical interventions in both febrile and critical stages.

Community mobilization – is advocating for empowering members of the community for a common purpose by taking ownership and fight for their rights to get the attention of the government to address certain community issues that has remained neglected for some time.

Community orientated/home-based vector control – refers to community-based dengue prevention activities aimed at eliminating vector from the home environment**.**

Compromised immune system – a body with a weak body defence system because of having other chronic medical problem or being too young (babies) to fight against an invading disease-causing agent**.**

Critical epistemology – refers to critical arguments on the discourse of logical meaning by justifying or rationalising the relationships between different theoretical practice concepts.

Cultural challenges in dengue prevention – refers to believes and customary practices such as “leaving water drinking containers over the graves in the within the home environment” promotes mosquito breeding and transmission of dengue.

Dengue control – public health efforts in organizing the reduction of dengue disease burden from the community.

Dengue emergence – is a global public health assumption that a new wave of dengue phenomenon has precedent backed by a uniformed overwhelming epidemiological evidence of increases general dengue incidences, prevalence and mortality.

Dengue epidemiology – study of dengue disease incidence (occurrence), prevalence (burden) and mortality (dengue-related deaths) per 100 000 population.

Dengue fever – a deliberating viral disease, a common public health problem of the tropics transmitted by an Aedes mosquito characterized by sudden onset of fever and severe pains in the joints and eye socket.

Dengue monitoring – refer to the action necessary to detect and forecast dengue epidemic activity which includes human-based dengue cases, entomological and laboratory-based surveillance and environmental risk assessments.

Dengue perceptions …. refers to the general feelings of being aware of the uncertain presence and circulation of dengue causing mosquitoes in the community.

Dengue prevention – personalised responsible activities aimed at preventing dengue transmission both at individual or family level

Dengue risk factors – refer to the factors influencing transmission of dengue in the community such as rainfall, increasing temperatures, social human activities such as overcrowding and lightering.

Environmental-friendly insecticides – any insecticides that has been made harmful for the survival of disease causing vectors but harmless or reduced risk of threat to the natural environment.

Global dengue strategy – refers to the WHO 2012-2020 plan for dengue control and prevention in which coordinated action among multi-sectoral partners is promoted to feature an integrated approach including vector management to sustain control measures at all levels.

Geographical temperature-based dengue endemicity – is when dengue disease has become endemic in an area influenced a conducive climatic temperature that favours the proliferation and breeding of vector and eventual transmission of dengue disease.

Innovative vector control methods- are improved ways of disrupting vector breeding sites or sources and reducing vector population from the communities**.**

Integrated Vector Management – a new rationalized vector control strategy endorsed by WHO (2011) to combine the usage of insecticide-based bed nets and screens, improved housing conditions, environmental protection and biological control.

Laboratory-based diagnosis – refers to confirmation or rejecting of a provisional or clinical suspicion of a likely disease case using a laboratory diagnostic procedure.

Long-lasting insecticides spraying – killing pests, insects including mosquitoes using pesticides that can last longer than usual

Man-made containers – refers to containers that lie around the home environment such as empty drinking containers, flower pots, and old tyres which poses risk of vector breeding and dengue transmission.

Miss-coding – is an act of deliberate or unconscious coding of a disease case into a different disease code based on clinical assumptions without laboratory confirmation.

Miss-diagnosis – is a clinical misjudgement of a disease case based on clinical manifestations without laboratory confirmation.

Pathogenicity – inbuilt ability of a virus or bacteria (or any organism) to cause, transmit disease and the degree of damage done to an individual or community at large during disease outbreaks.

Philosophical perspectives – refers to the love of wisdom in which worldviews about meanings of things and how their meanings are interpreted based on what one sees.

Potential barriers – are factors including the lack of skilled manpower, resources (transport, equipment), geographical terrain which disadvantages effective dengue control and prevention.

Public health policy – is a statutory document compiled using ideas, plans and actions with specific or broad-based targets or goals to reach over a shorter or longer period.

Public-Private-Partnerships – combining supportive actions to foster mutual corporative agreement to address public health issues.

Pyrethroids – are different insecticides used in vector control activities, particularly with both indoor and outdoor spraying

Secondary dengue episode – a recurrent dengue attack by a different serotype other than the serotype responsible for the initial attack (febrile stage) which often results in serious forms of dengue including dengue haemorrhagic fever (DHF) (critical stage) or dengue shock syndrome (DSS) (convalescent stage)**.**

Serological surveillance – blood-based laboratory study involving serum and other body fluids to confirm presence and circulation of an organism or factor of interest.

Sparse dengue surveillance data – refers to unsound or estimated epidemiological data that seemed unreliable for public health intervention for control and prevention of dengue.

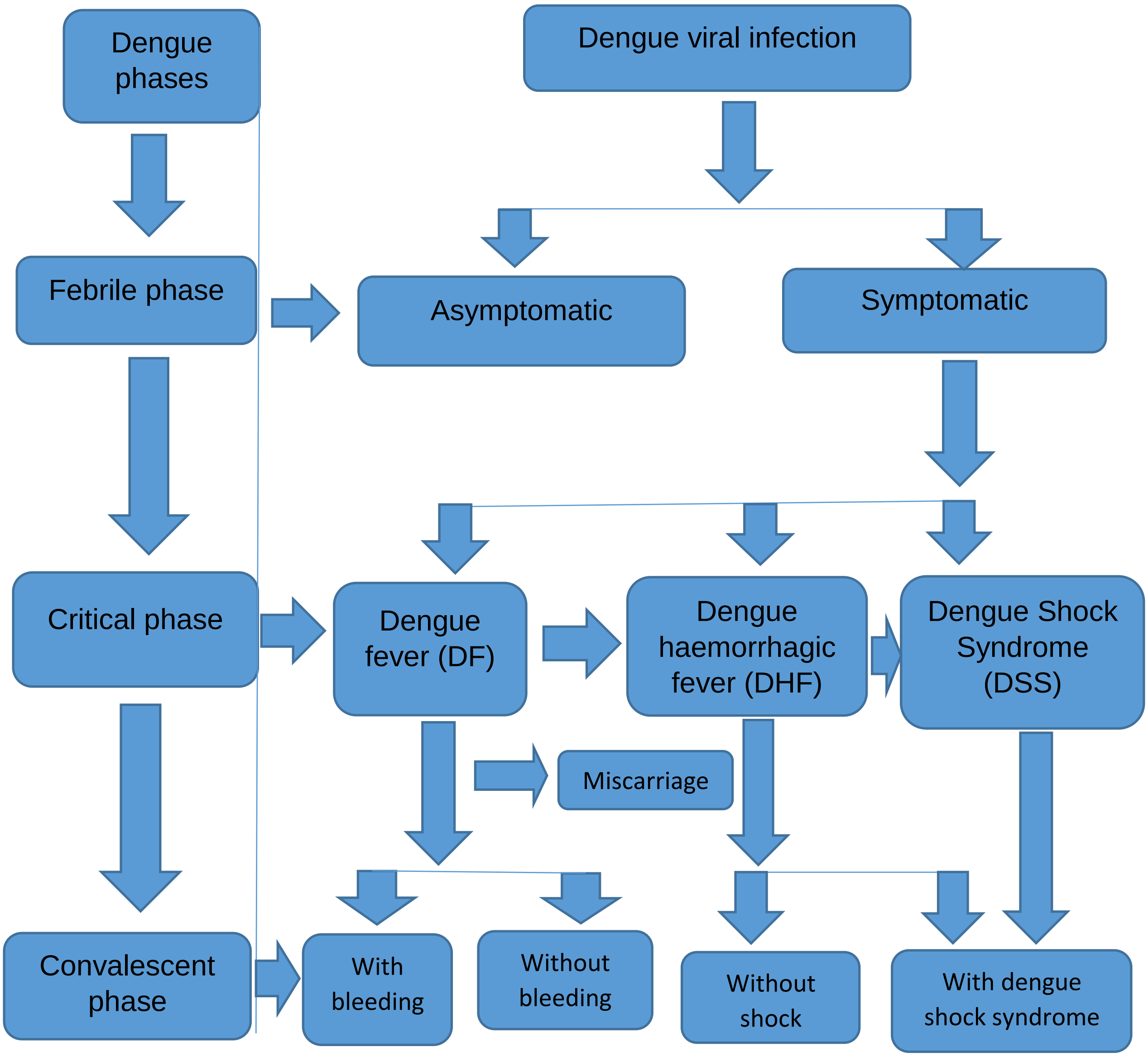
Targeted treatment – or evidence-based intervention in vector control is referring to public health activities aimed specifically to a target location or type of vector based on known epidemiological or entomological evidence.

Traditional vector control……. refers to old insecticide-based vector control efforts that have not been maintained due to shift in the attention especially in the prioritization and allocation of resources**.**

Tropical country – any vector disease-prone country located within the tropical zone along or close to the earth's equator experiencing birth dry and wet season each year with an estimated rainfall of 60 millilitres per wet-month.

Vulnerable populations – a group of people living with an existing illness, very young children, pregnant mothers at increased risk of an opportunistic infection. Healthy people living in a disease prone geographical zones known for increased risk of dengue epidemics who are also socio-economically disadvantaged also become vulnerable.

Appendix B: Flow chart of dengue disease process & classification



Source: Based on texts from Bhatt et al. (2013)