SYSTEMS MODELING FOR DYNAMIC ASSESSMENT ON APPROPRIATE TECHNOLOGY APPLICATION: CASE OF COCOA INDUSTRY IN ACEH, INDONESIA

DISSERTATION

Submitted to the
Graduate School of Science and Technology – Tokyo University of Science
in partial fulfillment of the requirements for the degree of
Doctor of Engineering

by

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TOKYO UNIVERSITY OF SCIENCE
2017

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This dissertation has been prepared under our supervisions and the candidate has compiled with the Doctor's regulations.

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ABSTRACT

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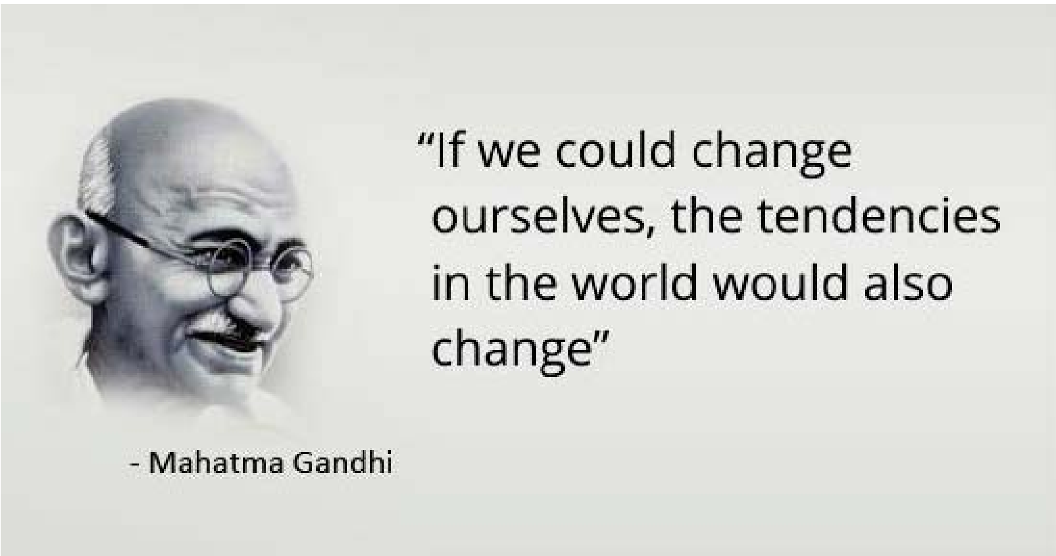
Vulnerability eradication has gained attentions among scholarly communities. The notion has also raised a further need to conduct scientific researches in a more systematic way and systemic thinking. However, there are less formal studies on the issue, particularly ones that show the way to conduct a complete vulnerability eradication from fundamental concept to a practical case. This research aims at providing an example of conducting vulnerability eradication over a known vulnerable region. Literature survey is conducted to find a fundamental thinking to do a proper vulnerability eradication. The concepts are then applied into a case study. The review show that empowerment is the correct paradigm for development purposes in a vulnerability eradication effort. Besides, appropriate technology emerges as a promising technological solution to do empowerment over vulnerable communities and their region. Next, cocoa industry in Aceh, Indonesia, is taken as the case study. In the case, appropriate technology is combined with postharvest engineering to empower farmers. It aims at reducing farmers' dependencies to intermediaries in doing required postharvest processing. The results show that the dependency would get nulled in less than five years, indicating that farmers are empowered after the period. However, the need may come back as farmers need to do a replacement routine on every technology that has reached its lifetime, while spending some of their savings for the reinvestment. Then, another exogenous new technology introduced in the tenth years is expected to further improve farmers' empowerment and reduce their vulnerability by producing less number of required technologies at the maximum availability factor while significantly improving the persistency of farmers' savings despite having periodical disruptions.

Keywords : Appropriate Technology, vulnerability eradication, community empowerment, reverse engineering

Devoted to all philosophers, technologists, engineers and scientists of Appropriate Technology



ACKNOWLEDGMENT

How times have changed. When I first entered the graduate school to pursue my doctoral degree, I started it with a mere goal: to get a doctoral degree. Practically, it began with a simple thought to conduct my research on the issue being investigated, that's it. However, it later appeared to be the beginning of a long-remembered journey accros islands, seas and continents, meeting and discussing with distinguished figures from all around the world with a unique spectrum of expertise. Looking at all efforts contributed during this research, I would like to acknowledge those figure, including practitioners, sceintists and decision makers, who have shown a kind willingness to give any valuable input, discussion or influences, even in its smallest form, particularly during the development of the model and/or surrounding issues, either directly or indirectly. A lot of gratefulness are addressed to Prof. Kelvin Willoughby (Skolkovo Institute of Science and Technology, Russian Federation, innovation and technological appropriateness), Prof. Anil. K. Gupta (Indian Insitute of Management, India, grassroot innovation), Prof. John Tarakan (Howard University, United States, appropriate technology), Prof. Marcel Sitiriche (University of Puerto Rico in Mayaguez, Puerto Rico, appropriate technology), Prof. Joshua Pearce (Michigan Technological University, United States, open-source appropriate technology), Prof. John Trimble (Howard University, United States, appropriate technology), Dr. Leuserina Garniati (Robert Gordon University, vulnerability studies), Dr. Lonny Grafman (Humboldt State University, United States, appropriate technology), Dr. Mariano Fressoli (STEPS America Latina, Argentina; grassroot innovation), Prof. Takeshi Arai (Tokyo University of Science – TUS, Japan, systems modeling), Prof. Kuntoro Mangkusubroto (Institut Teknologi Bandung – ITB, Indonesia, decision science), Prof. Utomo S. Putro (ITB, Indonesia, system modeling), Dr. Bartjan W. Pennink (University of Groningen, the Netherland, local economic development), Dr. Bambang Rudito (ITB, Indonesia, anthropology), Dr. Deddy P. Koesrindartoto (ITB, Indonesia, financial management), Dr. Luke Swainson (Australian National University, Australia, cocoa market access), Dr. Martin Stottele (Swisscontact, Switzerland, project management), Kitri Widaretna (USAID IFACS, Indonesia, community empowerment), Intan Nugraheni (Rural PNPM, Indonesia, community empowerment), Heny R. Estiningtyas (Gadjah Mada University, Indonesia, food technology), and many others who could not be listed one by one.

Furthermore, I got a precious experience to join the Young Scientist Summer Program held by the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. It was an incredible chance for me to work with numerous big names in science from all around the world just in a single place. Among others, I would like to express my gratitude for Dr. Yurii Yermoliev (Ukraine, supervisor), Dr. Tatiana Ermolieva (Ukraine, co-supervisor), Dr. Elena Rovenskaya (Russian Federation), Prof. Brian Fath (United States), Prof. Jeffrey Sachs (United States), Prof. Willi Semmler (United States), Dr. Joanne Linnerooth-Bayer (German), Dr. Warren Sanderson (United Kingdom), Dr. Gui-Ying Cao (China), Tanja Huber, Aleksandra Cofala, Ping Yowargana, Gardina Kartasasmita, Amalia Priyatna, Dr. Matthias Jonas (Germany), Dr. Aline Mosnier (France), Dr. Matthias Wildemeersch (Belgium), Dr. Wei Liu (China), Dr. David McCollum (United Kingdom), Dr. Narasimha Rao (India), Dr. Junko Mochizuki (Japan), and many other scholars at IIASA. Many thanks I also express for my officemates: Osama Ibrahim (Egypt/Sweden), Dina Subkhankulova (Russian Federation/United Kingdom), and Navid Rekabsaz (Iran/Austria), and all YSSPers 2016 for their supports during my stay in Austria and particularly at IIASA.

Next, I would like to express my highest respects for H.E. Tarja Halonen (President of Finland 2000-2012) and H.E. Heinz Fischer (President of Austria, 2004-2016) for the precious chance to delivering my thoughts and ideas in front of such two distinguished decision makers, including a rare opportunity to get compliments from two presidents in the same occasion and to receive invaluable inputs for my career, life and future works.

Then, last but no least, I would like to thank to my supervisor at Tokyo University of Science, Prof. Kiyoshi Dowaki, to whom I owe my pleasure to study under his supervision since almost five years ago. My biggest gratitude for the chances to collaborate with him in a self-encouraged way, a conditional work circumstance that has always been boosting my research spirit at its peak level.

Chiba – Japan, January 2017

Corinthias P. M. Sianipar

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Chapter I INTRODUCTION
Issues and Opportunities Underpinnings

> *"Swadeshi – local self reliance – is that spirit in us which promotes the use and service of our immediate surroundings to the exclusion of the more remote." (Mahatma Gandhi, 1969)*

I.1 Background

I.1.1 Vulnerability: An introduction

Vulnerability has become an important term in today's society. It is used by people across disciplines, including different scientific traditions in seeing and treating a particular phenomenon. From proposals on psychological vulnerabilities to engineering ones, from economics vulnerabilities to ecological ones, the term "vulnerability" has become a contested meaning (Adger, 2006). Each discipline and scientific tradition has tried to incorporate vulnerability in their own contexts, and has theorized vulnerability as they deal with it from their own perspective in every contextual vulnerable situation. While those disciplines and scientific traditions have proposed their understandings on vulnerability with interconnected meanings, there is no single agreed definition of vulnerability, meaning that the concept of vulnerability itself is rather contextual than general, and diverse rather than converged. The term itself, as a word, is defined as the extent of an observed entity to which it is exposed to potential harm due to its fragile foundation in facing challenges, particularly a shocked one such as natural hazard (Turner *et al.*, 2003a). The fragile foundation refers to the fundamental factors of an observed entity regarding its capabilities in delivering response, either natural or artificial, for external as well as internal challenges, both natural and artificial. Besides, the exposures are stated as the possibilities of an observed entity to experience potential harms in the future as the results of either past experiences, present circumstances, or possible future changes. In such understanding, vulnerability itself is the cause of future vulnerabilities as vulnerability is tightly related to fundamental factors of an observed entity, meaning that when a vulnerability produces weak responses to a challenge, the weak responses will accumulate previous vulnerabilities related to the challenge to be bigger vulnerabilities at the future in facing further challenges. Vulnerability, therefore, is highly possible to bring an immediate destruction of an entity (Bourdelais, 2005). Looking at the diverse definitions of vulnerability, including different approaches in dealing with vulnerability as well as the multi-facets condition of a challenge due to accumulated effects of a vulnerability, vulnerability needs to be stated as a dependent phenomenon to many facets of societal circumstances. View- and standpoint in understanding vulnerability, therefore, is rather an interdisciplinary than an isolated thought. Vulnerability can be stated as having multidisciplinary concepts from different perspectives yet almost useless in providing clear answer to overcome a challenge, or incorporated to other concepts as a basis thought in dealing with human-environment interaction (Cutter, 2003; Turner *et al.*, 2003b); however, vulnerability itself is standing as an independent understanding that waits to be approached from all facets of its complexity.

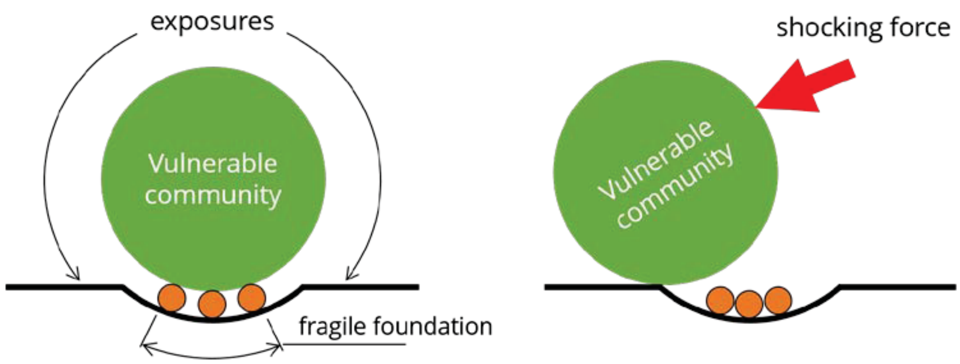


Figure I.1. Standing on a fragile foundation.

I.1.2 Vulnerable communities: Standing on a fragile foundation

In society, vulnerability is also becoming one of the most critical concerns in societal development. Recognized as the weak foundation of the extent to which an individual or group of people able to face challenges in surviving their existence, study on vulnerability is particularly focused at community level due to the importance of communal actions in incorporating global movements to regional and local practices (Leichenko and O'Brien, 2002; Few, 2003). Vulnerabilities attributed to a specific community are then aggregately taken to state the community as a vulnerable one. Vulnerability, therefore, is known as a basic characteristic of a particular community in a development and/or recovery contexts. In a development context, vulnerabilities of a vulnerable community refer to the exposures experienced by a specific community that cause the instability of internal communal system or interactions between members of the community in the development process, meaning that fundamental factors which support the community or the system have not reached a firm position and cannot support each other when several changes of challenges occur due to the progress of development (Figure I.1). On the other hand, vulnerabilities of a vulnerable community in a recovery process refer to the results of a crisis caused by disaster and/or either war or social conflict that affect fundamental stability of the community (Figure I.1), including its access to outside world. The instability then causes exposures of the community in their process to recover internal condition and its connection to other regions. Instability in a recovery process is highly possible to cause next crises. In the middle of either developing or recovery context, there is an intermediary one so-called prevention context. In such context, vulnerabilities of a developing community are the extent of exposures to which the community – that is in a development process – is possible to fall into a crisis. Therefore, based on those understandings vulnerabilities occur as the result of an unbalanced state between fundamental factors in a community either in a development progress or in a recovery process after war/conflicts or natural disasters, including the prevention context (Brooks, 2003; Hovden, 2004; Rigg *et al.*, 2005). Such phenomenon happens dependently among local/regional entities that construct the fundamental basis of local/regional resilience. Roughly-speaking, at community level vulnerabilities happen as the products of developing and/or recovery contexts, and vulnerable communities exist due to the vulnerabilities deeply-rooted in each particular community that critically lives in an unstable circumstance caused by continuous treats from either potential natural disasters or unconducive conditions in supporting strong growth and fundamental stability (Comfort *et al.*, 1999; Graham, 2006; Eisenman *et al.*, 2007; Mechanic and Tanner, 2007).

I.1.3 In developing countries: A major part of the world

Looking at the conception, vulnerable communities arguably exist in both developed and developing countries. As indicated by the understandings of vulnerability, each of either developed or developing ones has its own vulnerabilities that cause the exposure of national development progress, national recovery process, or national crisis prevention system. Such reason has become the root of widely-accepted argument in which any country could be stated as vulnerable (Downing, 1992; Adger and Vincent, 2005; Conley, 2009; Measey, 2010). Furthermore, the causes of vulnerabilities can be distinguished to five different conditions (Woodward *et al.*, 1998): destructive growth, poverty, political rigidity, dependency, and geographic isolation. Those conditions are possible to happen in any community, in any of developing and recovery contexts, and in either developed or developing countries; however, in Woodward's study those indicators indicated that vulnerabilities – in other words: vulnerable communities – are most likely to exist in developing countries. Such statement is based on the considerations in which each of those factors strongly occurs in any developing countries as the result of the developing state and are compounded by the instability of fundamental factors. While in many developed countries the fundamental factors of a nation or communities, *i.e.* economic power or societal resilience, have been firmly founded on solid resilience and can support each other in facing challenges, many developing countries still struggle to stabilize their fundamental factors due to their fragile foundation. Moreover, in fact 82.5% people all around the world in the year 2013 live in developing countries (PRB, 2014). Even if China is excluded due to its potential to become a new superpower country, the rests still cover 63.5%

of the world's population. By looking at those statistics and the highly-supported consideration in which vulnerable communities are mostly likely to exist developing countries, vulnerable communities have become one of the world's major entities and a very important facet of the future security of mankind (Morrow, 1999; Amexo *et al.*, 2004). However, the diverse and contextual understandings of vulnerability itself could become a problematic discourse for every authority and/or local body in any developing country in coping with the vulnerabilities of any vulnerable community in their own area. The fundamental instability of each particular community causes more difficulties in eradicating every contextual vulnerability. Besides, such barriers are worsened by accumulated vulnerabilities that produce further vulnerabilities. The barriers are also highly possible to trigger future crisis in local as well as surrounding area. In other words, eradicating vulnerability is a now-or-never deal, meaning that a failure in treating present vulnerabilities will cause much wider exposure in the future; on the contrary, right treatment will close the gate for other incoming vulnerabilities by strengthening and stabilizing fundamental factors of a vulnerable community.

I.1.4 Technology: An interdisciplinary solution

Considering the interdisciplinary perspectives of vulnerability, the instability of fundamental factors in every particular vulnerable community, and the wide exposure of developing countries to fall into crisis, any vulnerable communities require a cross-disciplinary solution that could support growth, vulnerability eradication, then strengthening resilience. In that spirit, technology comes as a powerful answer in delivering those purposes through only a single solution. Despite the contextual characteristics of vulnerability-related studies, technology itself has been recognized to have a critical position as one of the essential concerns throughout the world (Grübler, 1998). Technology has also gotten a unique positioning as one of the cornerstones of vulnerability eradication in today's society (Füssel, 2007). Particularly since the Industrial Revolution in the late 18^{th} century, technology has changed human perspectives on their ways of doing things (Wren, 2005). After such phenomenal history, whatever the object is, wherever and whenever people as either individuals or human institutions such as communities, governments, or business, require a booster to significantly enhance their efforts in the pursuit of vulnerability eradication and reinforcing resilience, technology would be a common choice among other ones (Liverman, 1990; Willoughby, 1990). Of course, there are people whose sentiments have been reluctant in supporting those facts. They are ones who state that the belief in the capacity of technology in providing answers for the reduction of vulnerability – even if in its smallest form – must not be posited as the ultimate and only reason to put technology above any of its counter facts. Such kind of people has also toughly pointed their finger at technology as the main cause of future human vulnerability problems such as environmental and health (Schumacher, 1973; Wisner and Luce, 1993; Ehrenfeld, 2008). However, people with negative perspectives on technology are unable to refuse the fact that even if a technology has many negative effects imposed to surrounding space and environment, the answer of their concerns would be mainly provided by technological advancements (Kemp, 1994; Robards and Alessa, 2004). The concerns, therefore, have changed to become only a rhetoric in any effort of vulnerability eradication. In practical level, the positioning of a technology in vulnerability eradication is frequently focused on environmental issue as the response or prevention to natural phenomena surrounding a community (Cova, 1999; Tobin and Montz, 2004; McEntire, 2005); however, later approaches have begun to cover other kinds of vulnerability such as social, political, and/or economic vulnerabilities (Liverman, 1990; Cutter *et al.*, 2003; Adger, 2006). In short, the incorporation of technological advancements in eradicating vulnerabilities has changed the whole movement. Since technology is posited as a comprehensive solution produced from interdisciplinary perspectives, the implementation of vulnerability eradication has become much robust for strengthening fundamental factors of a particular community. It also stabilizes cross supports between those factors in establishing societal resilience of the community, including early groundwork to deal with undesirable impacts of technology itself.

I.2 Problem Statement

I.2.1 Common technological solution: Advancing through transfer

Furthermore, as their attempts to eradicate their vulnerabilities and stabilizing fundamental factors for national resilience, including the pursuit of international recognition to become developed ones, developing countries begin to adapt many approaches from Northern hemisphere to implement their strategy (Haque, 1999). Following the terminology transformation of technology from only an artifact to be a more systematic technical enhancement of related processes (Grübler, 1998), developing countries have begun to incorporate such understanding into their development strategies. Approaches and solutions for technological advancements in vulnerability eradication, therefore, are adapted from developed countries to enhance practices in many developing ones. In that spirit, technological transfer has become a recognized approach to massively bring technologies from developed countries. In technology transfer, technologies – usually ones with high technical specifications and are common kinds used in the Northern hemisphere – are brought from developed countries. In those countries, a technology is seen as a universal solution for a certain extent of problems; hence each scientific discipline related to the purpose of a technology discretely contributes its expertise in developing the technology in order to unifying its technical specifications. In that scheme, a technology is treated as a multidisciplinary solution, meaning that each scientific discipline becomes a separated part of solutions embedded in the technology. While the technology is brought to be a technological solution for a particular vulnerable community, the multidisciplinary approach is consequently brought together within it; however, vulnerability eradication is rather cross-disciplinary than multidisciplinary, meaning that every technology from developed world is not suitable enough to eradicate vulnerabilities in every contextual situation from all problematic facets simultaneously. It is due to universal technical specifications to cover the extent of problems in some distinctive scientific disciplines to which the technology needs to solve in developed countries. Also, massive technological transfer in order to support vulnerability eradication in vulnerable communities do not practically obliterate all obstacles in its implementations in any developing countries. Even if some alternative concepts such as appropriate technology (AT; Sianipar *et al.*, 2013b) and grassroots innovation (Gupta *et al.*, 2003) have been introduced as the intermediaries in adapting approaches from more developed countries, some difficulties are triggered by obstructive circumstances in many developing countries. Those situations occur because developing countries are still left behind in many essential aspects compared to the profile of necessary supports in many developed countries wherein previous approaches were first developed.

I.2.2 Fundamental differences between countries

In fact, developed countries have already established strong national resilience as the result of stabilized fundamental factors, *i.e.* economic prosperity, social welfare, *etc.*, which then affect the correlation between widely-accepted constructs of national growth and wealth distribution to the choice of technology. Such conditions happen as the results of some applicable assumptions taken in many developed countries. For example, regarding economic issues developed countries do not have much problems in the economies of scale compared to developing ones (Kaplinsky, 1990); or, people in more developed countries tend to have relatively low variations in defining social capital, meaning that they tend to act correspondingly with the direction of any other citizen in achieving social goals (Knack and Keefer, 1997). Although in several developed countries there are diversity of conditions and trade-offs, including critical vulnerabilities that are possible to make them fall into crisis, every fundamental factor in those countries would support one another among factors in facing worst challenges. It means that a weakness in one factor would be overcome by improvements in other ones.

Therefore, the steady condition – as stated by Kaplinsky (2011) – refers to the time when there is a homogeneity of behaviors between fundamental factors of a country. Furthermore, such nearly-perfect condition also affects any technological choice. Due to the overwhelming supports both from government and the civilized society, technological changes are enormously concentrated at capital intensive techniques (Clark, 1985) by interpreting environmental issue through the rate of impacts imposed per contribution to market needs (Kemp, 1994). In that term, technical qualities become the main goal of technological advancements due to the accessible resources for reaching any purpose. On the other hand, developing countries arguably struggle in different settings. Circumstances and national capabilities in their own situation are not strong enough compared to which developed countries have achieved in order to eradicate vulnerabilities and supporting national resilience (Feng, 2001; Fields, 2002; Ahmed, 2009). Huge varieties, *i.e.* in economic capacities and/or social goals, have decomposed developmental efforts in many developing countries into detached entities, from an integrated national strategy into separate works in each targeted area. Such huge disparities have made some approaches focusing on unique conditions in each area to be an essential medium to deal with any existing diversity. Still, the problem in direct adaptation of approaches from developed countries to developing ones, including advances of technology through technological transfer, remains same (Plenert, 1997). Enormous diversities that commonly occur in many developing countries are not adequate to do an extensive application of approaches from Northern hemisphere due to different basic mentalities compared to the original ones (Sianipar *et al.*, 2013c). Different to developed ones, many developing countries – with all of their limited capabilities – are unable to get adequate control on all of discrete entities throughout their governance in order to ensure vast vulnerability eradication through all of its interdisciplinary focuses. In terms of technological changes, they obsessively attempt to overtake technical capabilities of developed countries by, ironically, neglecting the needs of their own citizens.

Also, such fascinating effort is very dangerous because it exposes further vulnerabilities that may trigger a huge potential of technological disasters (Steenhuiss and de Bruijn, 2001). The application of technological advancements for vulnerability eradication, therefore, is affected by those mentalities.

I.2.3 In brief overview of some developing countries

An example for above condition comes from the world's fourth most populous countries and also the third biggest developing countries: Indonesia. With its 249.5 million population, it covers almost 3.5% of world population (PRB, 2014). While other big developing countries are continuously showing their substantial growth in conjunction with significant development of their technological advancements for vulnerability eradication, the story of Indonesian remains stagnant due to the huge exposures to crisis as the result of fundamental instabilities and social inequality. Countries such as China, India, Brazil, and Mexico have even massively had to interchange between their growing potentials and technological transfer for vulnerability eradications conducted both in their own area and in several developed countries as their respective partners (Dechezleprêtre *et al.*, 2009). In China and India, there is a significant decrease of dependencies to single directional aids from developed countries due to the rapid growth in economic prosperity and technological changes. While China is recognized as a new world's economic superpower that is followed by its radical advances in technology developments, on the contrary India has its widely-spread technology developments from advanced ones to social innovations that strongly affect its ongoing economic growth. Besides those two, Brazil and Mexico have already maintained low technical vulnerabilities and good technological capabilities in their current state, including growing strategic industries and relatively similar culture to their respective developed partners. Those situations then produce smooth transfer of technologies despite the existence of social inequalities. On the other hand, technological change for vulnerability eradication in Indonesia is arguably stagnant in spite of the growing number of industries. In Indonesia, vulnerabilities occur due to both its developing state and the huge potential of natural disasters as the two conditions that strongly affect many facets of people's life (Chauduri *et al.*, 2002; Dasgupta and Beard, 2007; Souza *et al.*, 2007; Garniati *et al.*, 2014). Also, the term vulnerable communities is particularly attributed to people live in rural area, especially for those who work in low-tech industries such as traditional or transitional farming. In fact, of the Indonesian population more than half live in rural area and they largely work as farmers or in water-related jobs. Such kind of communities is then becoming more and more important due to the widening inequalities between urban and rural area. Their massive portion of Indonesian population gives a notion that they have big influences to national competitiveness. It means that Indonesian authorities have to take their risks and opportunities to target any vulnerable community in developing societal capabilities to reach higher national growths. To do so, some approaches have been proposed. On one side, technological transfer from developed countries is posited as the booster in achieving sustainable growth (Putranto *et al.*, 2003; Wie, 2005). On the other side, Appropriate Technology (AT), as a promising technological approach to deliver a comprehensive technical solution in a limited condition, is posited to provide a technology with sufficient technical performance at affordable price (Sianipar and Widaretna, 2012; Garniati *et al.*, 2014).

I.2.4 The problems arise

However, current practices of those approaches do not reflect the real form of vulnerability eradication. Huge numbers of advanced technologies are purely imported, *i.e.* by Indonesia, from developed countries without proper adaptation, meaning that technologies are taken for granted to pursue rapid economic growth but ignoring indigenous capabilities of local people; besides, AT is becoming important but is implemented through a laboratory-based development process in a workshop behind closed doors with least participation of targeted community members (Wie, 2005, Garniati *et al.*, 2014; Sianipar *et al.*, 2013c; Goodier and Moseson, 2013). Those conditions have made technology designers to: often ignore community empowerment, including local context and values; tend to have an exclusion of traditional ways of knowing; have a denial or devaluing people relationships; and strong commitment to industrial (military-like) working styles (Riley, 2008), by which implementation of technological changes and AT in Indonesia is increasingly difficult due to: (1) questionable technological appropriateness; (2) top-down approach to local needs; (3) low technological diffusion; and (4) weak support from local entities (Yanu *et al.*, 2013; Juwaini, 2013). For example, the design and development processes of some "appropriate" technologies which might help people in some particular regions in Indonesia to improve their existing processes, *i.e.* improved ship for fisheries (Wibowo, 2013), or to improve the product of process, *i.e.* analog rice (Prastowo, 2013) and nanotechnology (Rochman, 2013), are conducted in almost no direct participation of local people. In other words, those technologies are the product of almost all aforementioned difficulties in Indonesia (Yanu *et al.*, 2013; Juwaini, 2013) which have made them to be stated as "given technologies" rather than the products of inclusive development. Looking at above facts and conceptions, the real problem in the implementation of technological change and AT is not on the vulnerabilities of targeted communities. The problem is the approach consisting methods or techniques to do technological change and developing AT. In current practices, either technological change or AT development neglects the existence of each other, yet field implementation requires intermediation of those approaches in contextual matter as a means to eradicate vulnerabilities and strengthening local resilience through "appropriate" technologies; thus, technological solution for vulnerability eradication needs further development on its approach to strengthen the concept and perfecting the practices of vulnerability eradication.

I.3 Research Objectives

Hence, conducting technological advancements and AT in a single timeframe and place needs to incorporate local practices and has to empower local people. Problems discussed above have given notions to intermediate two counterintuitive approaches: technological changes through technology transfer and technology development based on AT approach. Also, there are at least two things that have to be rigorously explored in order to do technological changes for vulnerability eradication. At conceptual level, technological changes for vulnerability eradication requires a clearer understanding to empower people rather than only giving technology to do local development. In terms of its practice, a new framework is required to intermediate the mentality of technology transfer and the spirit of local problem solving. In addition, the intention of bottom-up approach in implementing technological changes for vulnerability eradication in a vulnerable community may also affect the choice of developmental paradigm taken as the basis of any concept and practice. Empowerment as an alternative paradigm which offers more bottom-up process compared to typical development needs to be explored regarding technological solution for a vulnerable community. It may become the entrance point of deeper diffusion of a technology to local process in order to maintain the continuity of technological changes and the consistency of vulnerability eradication. This research, therefore, has the following objectives:

(1) Revisiting the concepts of developmental purposes and technological changes for vulnerability eradication in vulnerable communities, including early form of framework to theorize research gap.

(2) Expanding the theoretical framework to be a practical framework to conduct the application of a technological solution for vulnerable communities.

I.4 Research Questions

Then, in order to meet those research objectives, this study has to answer these following research questions:

RQ1 What kind of developmental purposes and technological changes suitable for vulnerability eradication in vulnerable communities?

RQ2 How does anyone assess the systematic impact of a technology for a vulnerable community?

RQ3 How to apply such guidance in a field application?

Chapter II LITERATURE REVIEWS
Conceptual and Theoretical Reconnoitres

"Unless we build on the resources in which poor people are rich, the development process will not be dignified and a mutually respectful and learning culture will not be reinforced in society." (Anil Gupta, 2013)

II.1 The development paradigm and its implementation

II.1.1 Development: Single directional changes

Development is the common word used to represent an effort in changing one condition to a better condition. Development is recognized as a product of the evolutionary process (Bonner, 1958; Rist, 2002; Kothari, 2005b), meaning that even if a slight change occurs in a narrowest timeframe toward a better situation of an existing state, development happens. In this understanding, 'change' becomes the key word for development. Change and development happen at the same time, simultaneously. In particular, development refers to a positive change, meaning that the next condition has to be better than the previous one.

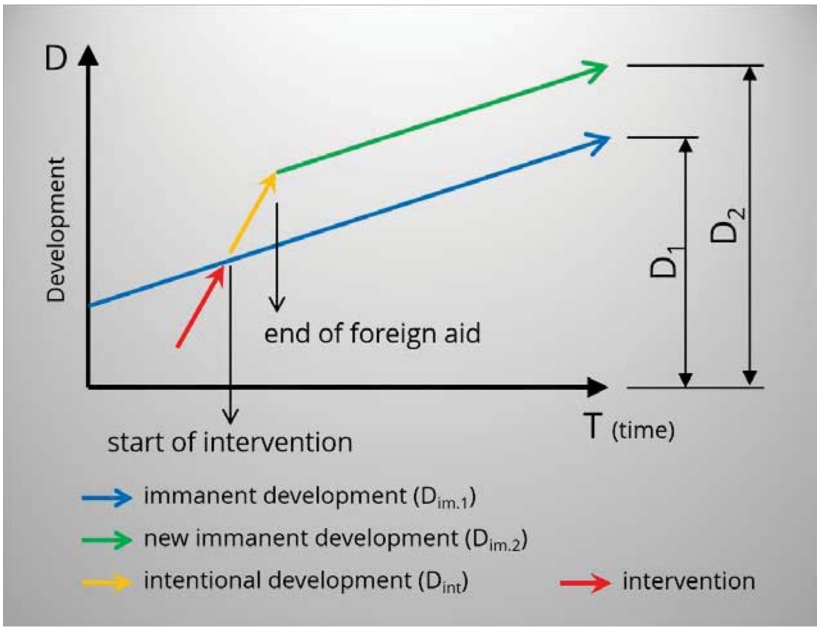


Figure II.1. Immanent and intentional developments.

Furthermore, development, in terms of the direction of societal development flow path, is stated as having two different forms (Cowen and Shenton, 1998): (1) Immanent development; and (2) Intentional development (Figure II.1). Immanent development (Figure II.1, D_{im}) is stated as a developmental pathway in which people, or their society, are changed driven by common progress in a set of interrelated factors in their own society such as science, technology, governance, *etc*. On the other hand, intentional development (Figure II.1, D_{int}) is often taken by interventionist. It is defined as a pure "push" developmental effort in which government and/or non-governmental organizations implement focused programs/projects as a means to direct the changes (development) of developing people to achieve better conditions. These two forms of development occur together producing a development ratio (Figure II.1, D_2/D_1), and, as stated by Morse (2008), the changes oscillate between immanent development as the normal ongoing changes in a society and intentional development as the directed intervention to ongoing progress as a means to "push" the development process in achieving better result (Figure II.1, $D_2/D_1 > 1.0$) for targeted people/society. These theoretical understandings have become the basis of the current development paradigm in which the parallel constructs of immanent and intentional developments shape development as a package of single directional and systematic partnerships from "developed" parties toward "underdeveloped" ones (Pieterse, 2000; Schuurman, 2002). In other words, development is related to the idea of modernity (Willis, 2005), meaning that there is a radical term in distinguishing "developed" parties and "underdeveloped" ones by stating that anything attributed to "underdeveloped" parties is stated as obsolete, and the better and best (modern) things have only been acquired by those in developed regions.

II.1.2 Developing vulnerable communities: A legacy of colonialism

In terms of the implementation of developmental efforts for vulnerable communities, the development paradigm is often considered a repackaged form of colonialism (Sidaway, 2007) from the "powerful" (developed parties/countries) to "powerless" (vulnerables communities/countries), meaning that there is a clear difference in treating vulnerable communities as the object of development as a means to maintain the power and control created and driven by "powerful" ones over the world (Mathews, 2004; Simon, 2007; Sianipar *et al.*, 2013b).

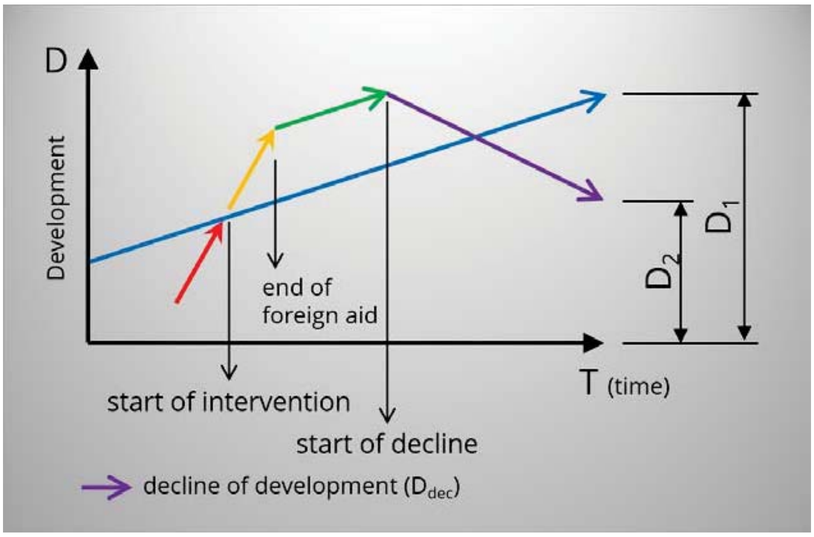


Figure II.2. The decline of development.

In vulnerable communities, immanent development is an illusive process due to the inability of the members of a vulnerable community to seek advancements of influential factors such as good governance or scientific innovations. Instabilities also become a barrier of those advancements due to potential conflicts caused by the changes of their way in doing business-as-usual. In other words, immanent development in vulnerable communities "has no defined endpoint" (Morse, 2008), meaning that a vulnerable community is fully capable of doing their activities as they have done it before, yet their vulnerabilities bring the immanent development nowhere except moving along the same trajectory without achieving significant progress. Furthermore, intentional development directed by more developed parties toward vulnerable communities often renders the community condition actually less than the previous business-as-usual. Even if an intentional development has been arranged as a means for developing vulnerable communities in terms of building capacity and social capital (Phillips and Pittman, 2009), it often fails to deliver on promised growth resulting in a decline in future development (Figure II.2, D_{dec}). Scholars have suggested this is because this type of development is constructed by those who control the power in developed parties and intentionally keep the hegemony of capitalism and/or neoliberal agenda (Escobar, 1992; Rahnema and Bawtree, 1997; Hart, 2001; Mathews, 2004; Khotari, 2005a; Nustad, 2010). This understanding has made the relationship between the subject and object of development more clear: vulnerable communities become only the object of development controlled by more developed parties, a developmental agenda driven by the interests of the developed ones. Besides, intentional development for vulnerable communities commonly produces a systematic top-down destructive intervention to immanent development inside the communities, meaning that there is disruption of the usual local practices which then triggers further vulnerabilities, including poverty (Kothari, 2005a; Rist, 2007). Then, the oscillation of changes between immanent and intentional development in/for vulnerable communities produces further instabilities in the communities, due to potential local conflicts among locals. The continuous oscillation of changes then becomes cyclical towards the weakening of vulnerable communities (Figure II.2, $D_2/D_1 < 1$).

II.2 The paradigm of empowerment and its implementation

II.2.1 Empowerment: The delegation of developmental power

In order to avoid the harmful effects of the development paradigm toward a targeted people/society, researchers proposed an alternative way-of-thinking of development by reconsidering the weight of each form of development towards a more bottom-up construct. This is known as “empowerment” (Friedmann, 1992; Narayan, 2005; Cornwall *et al.*, 2010; Sianipar *et al.*, 2013b) and is taken as a powerful approach in the developing and recovery contexts. In fact, it is similar with the basic understanding of typical development: change. Empowerment views change as the driver of progress toward a better condition; however, it does not force positive changes based on the interest of intentional development purely from developed parties. Empowerment risks ensuring the survivability of targeted people/society by putting local matters and manners, including indigenous knowledge, interest, and social goals, as the canvass of their own development (Narayan *et al.*, 2000; Sianipar *et al.*, 2013b). Besides "change", the root idea of empowerment is "power" (Eyben, 2004; Moose, 2004). In terms of immanent development, "power" is the capability of locals in their pursuit of advancements based on influential internal factors. On the other hand, "power" in intentional development is the capability of intentional intervention toward the ongoing immanent development as a means to transform the current immanent development into another form of business-as-usual.

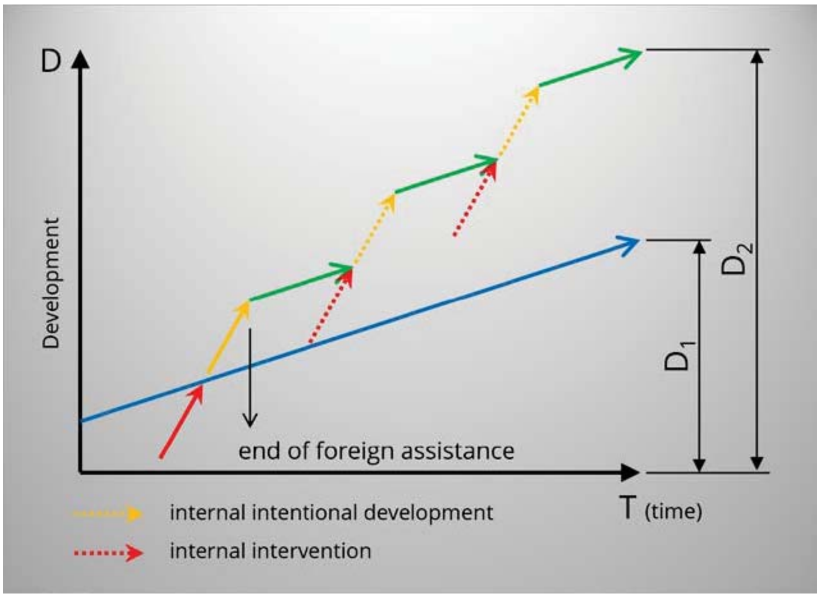


Figure II.3. Immanent and intentional developments in empowerment.

In the development discourse "empowerment" is a critical subject related to the quality of life through self-assessment and self-problem solving (Narayan, 2000; Germann and Wilson, 2004; Luttrell *et al.*, 2009). In empowerment, the critical differentiator from the developmental paradigm is the delegation of power (Alsop *et al.*, 2006), meaning that power is not fully dependent upon and is not concentrated based on the interest of more developed parties; however, power is posited as the capability of locals for assessing and solving their own challenges and providing solutions based on local circumstances, including the incorporation of control on social goals, justice, and political dynamics (Fawcett *et al.*, 1995; Lee and Koh, 2001; Minkler, 2005). In that spirit, power from developed parties is posited as the power of assistance, meaning that there is a significant shift of the intention from foreign parties towards targeted people/society. Their intentional development need to be placed strongly at the beginning of intervention, yet it has to be pulled out over time as a means to provide more and more space for locals to do their own intentional development through local innovation or invention (Figure II.3). Furthermore, alongside the long history of empowerment theory, researchers have agreed that societal transformation, the continuous adaptation of change and power, is the path to empowerment. While Lukes (1974) had stated that "power" could be distinguished on several levels by which people/society continuously redefine their own challenges and solutions, Page and Czuba (1999) & Ferguson (2010) highlighted the importance of transformative and adaptive power expansion, meaning that the transformation process need to transform "power" as the driver of change to empower people/society through a set of local solutions for facing the changes of present and future challenges. In conclusion, the empowerment paradigm emphasizes the delegation of rights towards local people/society to take more control of their own development by continuously redefining their own social goals and constantly adapting their response to the changing situation in the pursuit of the transformation to a better state through internal immanent as well as intentional development. It is not fully removing the partnership with more developed parties, yet the developed ones have to shift their role to be assisting decision-makings rather than being the primary decision makers.

II.2.2 Putting people first: Empowerment beyond development

In the relationship with vulnerable communities, the empowerment paradigm is a refocused form of developmental efforts towards the elimination of vulnerabilities through the societal transformation process within targeted communities over time (Wilson, 1996; Lacy, 2000; Cummings, 2001; Diaz-Puente *et al.*, 2009). It is the extent to which decentralized development is implemented (Alsop and Kurey, 2005; Alsop *et al.*, 2006) from parties with greater bargaining strength towards vulnerable communities. In the development paradigm, foreign aid is driven by the interests of more developed parties for targeted vulnerable communities by which vulnerabilities (Vs) are often ignored (Figure II.4). Consequently, communities often become more vulnerable. On the contrary, empowerment offers a consistent eradication of vulnerabilities by ensuring communities control over power for themselves, even if there is no access to foreign aid or external resources. The assumption is that vulnerable communities will surely survive by continuously eliminating their own vulnerabilities through internal (rather than external) immanent and intentional development.

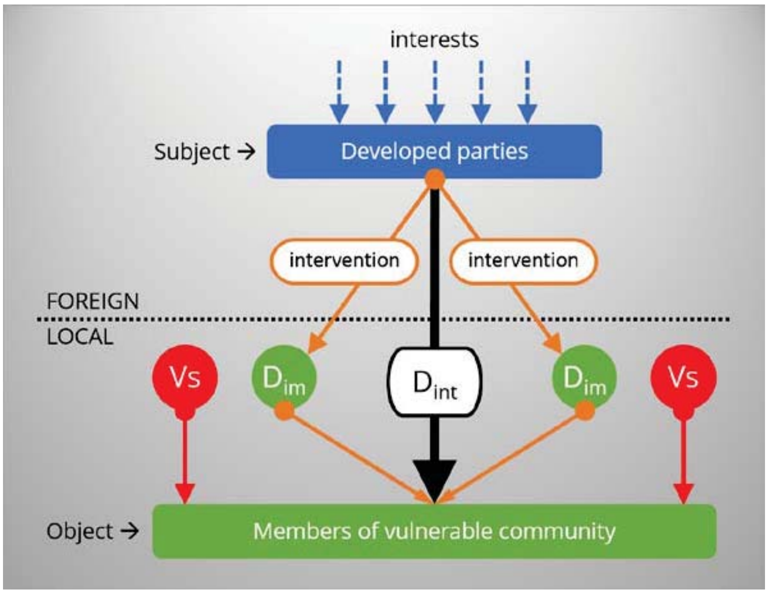


Figure II.4. Subject – Object in development paradigm.

Empowerment, in its implementation, has been demonstrated as having multidisciplinary practices such as the pursuit of better social conditions, reducing inequalities, communal health treatment, renewable energy, *etc.* (Tracy *et al.*, 1996; Rifkin, 2003; Wilkinson and Pickett, 2009; Mamphweli and Meyer, 2009;

Andersen *et al.*, 2011). Looking at the broad potential implementations of empowerment, the idea of empowerment goes beyond development and has converged to put local people before any developmental effort[1] (Figure II.5). In order to strengthen the foundation of empowerment, some local entities are included in supporting the members of vulnerable communities. Parties considered as local entities include: local governments and local NGOs through their community empowerment programs (Mongkolnchaiarunya, 2005; Brockington, 2007; Kasmel and Andersen, 2011; Kabeer *et al.*, 2012). Also, looking at the definition of localized efforts in empowerment, some other entities like foreign NGOs and/or other forms of international aid (Power *et al.*, 2002; Stiles, 2002; Haque, 2004) can be considered as local entities as long as they stay locally with vulnerable communities, and they have to be excluded from local development when leave the local area.

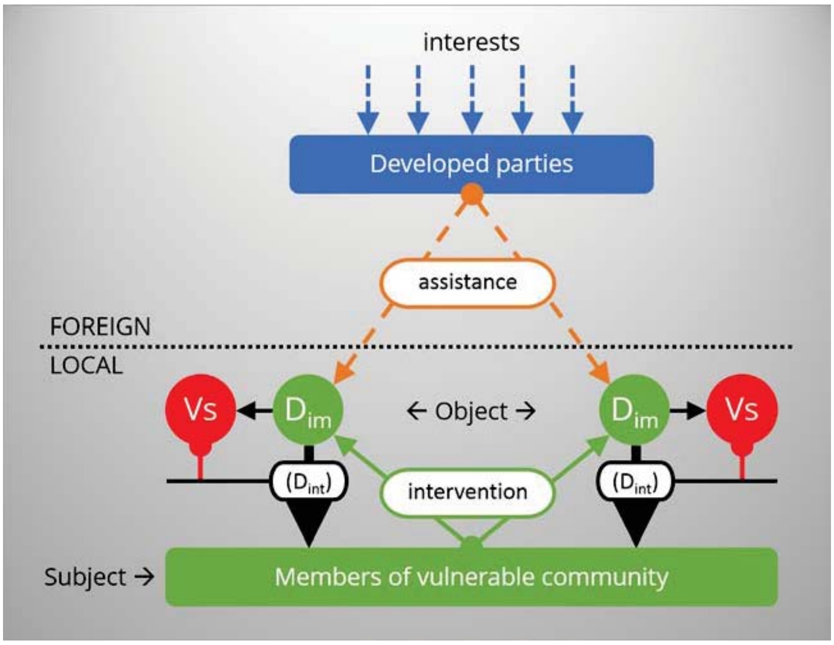


Figure II.5. Subject – Object in empowerment paradigm.

[1] People is posited as the subject, meaning that the delegated power is given to the members of targeted vulnerable community, not foreign-based system, as a means to avoid the undesired effects of vulnerabilities of local system and circumstances, and to construct a stronger foundation of internal immanent and intentional developments in response to future transformation of challenges.

Any of those entities (local governments, local NGOs, foreign NGOs, *etc.*), therefore, need to be aware of the critical position of the members of vulnerable communities in empowerment. This means that any effort they take will enhance success if and only if they can ensure the human development of local people in terms of capability in managing themselves and surrounding resources, and also handling the changing circumstances. In short, empowering vulnerable communities is not as easy as giving aid to stimulate development. Empowerment is a continuous internal process in eradicating vulnerabilities through societal transformation of vulnerable communities. Empowerment needs the members of targeted vulnerable community to take the lead, meaning that empowerment can be triggered from any supportive source but has to be led by local people to deal with their own area and its contexts in conformity with their own social goals.

II.3 The paradigm shift: Empowerment-based technological changes

As empowerment aims to ensure the capability of people in managing the changing circumstances, the members of a targeted vulnerable community require support from other facets of developmental efforts. Technology, as an important facet in any kind of development, is considered as a supportive tool and a powerful transformative driver for societal development (Willoughby, 1990; Grübler, 1998; Wren, 2005). Thus, technology has become a fundamental facet in both development and empowerment paradigms. Also, Rip and Kemp (1998) stated that technology is a part of societal transformations, and not an external driver of them. Those statements have given credence to the important notion that technological changes can be posited as an internal driver of vulnerable communities in their societal transformation. This means that changes in technological innovation in solving local problems become internal intentional development designed to advance immanent development forward using local resources and capitals. In other words, technology can be a driver of shift of paradigm in developmental works from development to empowerment if positioned correctly.

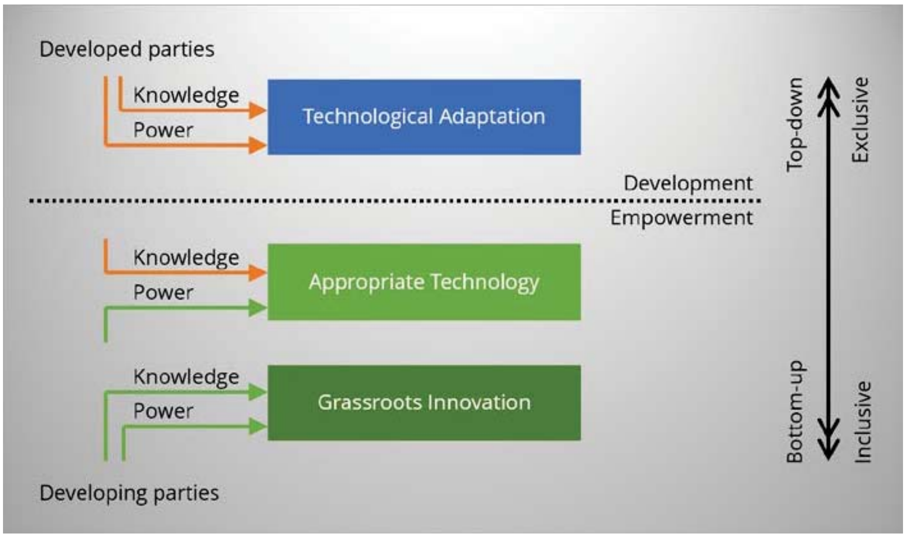


Figure II.6. The paradigm shift.

Furthermore, technology as a part of societal transformation must be considered as in these two developmental theories. In fact, technology development based on the development paradigm is quite different from technology development within the empowerment paradigm (Figure II.6). Technology development which is founded on the theory of the development paradigm refers to the approach that puts technology as a given solution in a given condition. The term given solution means that a technology is only given to the members of a vulnerable community, meaning that even if there is an effort to conduct technological transfer, a technology is merely brought from the outside to be used in a local process. Even if there are some adaptations to the circumstances experienced by a targeted vulnerable community, *i.e.* economies of scale, the requirements for designing and developing a technology is that the technology transferred is developed based on a set of rigid specifications. Also, the term "given condition" means that information about the field conditions in a specific vulnerable community are assumed to be well understood by foreign partners from third party medium such as NGOs or local government, meaning that there is a limited direct interaction between technology designer/developer to local people in constructing the concept of required technology. The partnership between a community and a more developed party looks like the old-time relationship between from a customer and a producer. In this regard, transferred technologies are "foreign" technologies, and the work to transfer the technologies is known as technological adaptation (Lee, 2005; Chandra, 2006) by considering the extent to which a technology is adapted to local circumstances of targeted vulnerable community.

On the other hand, the empowerment paradigm emphasizes technological solutions with more focus on existing capabilities and the abilities of local people in a vulnerable community. Based on this understanding, any approach based on the empowerment paradigm is then characterized as a more bottom-up approach. In this paradigm, rather than technological adaptation (Figure II.6), technology is developed as grassroots innovation (Gupta *et al.*, 2003; Smith *et al.*, 2014) which is the alternative approach for the members of a vulnerable community in providing a technological solution for their own needs and wants. Grassroots innovation, as indicated by its name, is an independent technology design and development resulting from minimal foreign intervention. It is characterized as an inclusive innovation process based on existing local processes, problem solving approach, and expectation of outcomes that have already been embedded based on the knowledge of the members of a vulnerable community. In other words, technology design and development is conducted by encouraging local innovation to foster development, meaning that local people are empowered as a means to deliver their own problem solving through technological solutions. Although in some developing countries grassroots innovation is triggered by national policies as well as other interventions (Sefyang and Smith, 2007), the implementation is conducted by local people as the initiators of a technological solution. Looking at this approach, grassroots innovation requires the relatively independent from foreign intervention. Conversely, the lack of readiness of the members of a vulnerable community means that grassroots innovation cannot be enforced into solving community problems and eradicating vulnerabilities through technological solutions.

Then, in the middle of technological adaptation and grassroots innovation approaches, appropriate technology (AT) emerges as another empowerment-based technology design and development approach (Figure II.6). AT was first initiated by Schumacher (1973) who stated that providing technology for less developed people requires a different approach than the commonly used method in developed countries. Actually, grassroots innovation arose from the AT movement, yet grassroots innovation is directed toward a full participation of local people while AT is continuously taken as an approach to intermediate "foreign" knowledge that is well integrated with local requirements as a means to build an "appropriate" technology for a specific vulnerable community (Khanna *et al.*, 2008; Murphy *et al.*, 2009). This means that AT is an intermediate concept recognizing AT as an "intermediate problem solving" approach. Furthermore, AT as a technology is also known as "intermediate technology". It means that a technology is designed and developed to be posited as an intermediary technology in order to deliver better results before a more advanced technology is applied. This approach is implemented to deal with any related requirements for more advanced technology in local areas, meaning that people are prepared in the process to be able to use a more advanced technology by learning from an intermediate technology which is designed and developed for this purpose (Eicher, 1999; Fu *et al.*, 2011). In short, AT tends to stimulate the empowerment of the members of a targeted vulnerable community to be able to achieve a better state by incorporating a more bottom-up approach in technology design and development without ignoring knowledge from foreign assistances (Sianipar *et al.*, 2013c).

Looking at those three kinds of technology development for vulnerable communities, the paradigm shift from development to empowerment refers to the shift from development-based approach to empowerment-based approaches of which three have been described. From the three described were technological adaptation, AT and grassroots innovation. In order to shift toward the empowerment approach and deliver immanent and intentional developments, decision-makers must shift from a purely foreign-based developmental framework (development is intentionally driven by interests of parties with higher bargaining strength) to a more inclusive one towards the existing capability of the members of a targeted vulnerable community. The delegation of power is not necessarily interpreted as full independence, yet the implementation is based on the redistribution of power, meaning that the ultimate control of the developmental progress in a vulnerable community does not refer to the higher bargaining strength of foreign parties but to the members of the community who are responsible for continuous strengthening and transformation of internal immanent and intentional developments in their own futures. The technology level shift refers to the redistribution of incorporated inputs, the focuses of process, and desired outputs of technology design and development. Any input for the design and development of a technology needs to be refocused to give more weight to local circumstances. The assistances from foreign parties should be repurposed to conduct possible improvement based on local input without ignoring existing capabilities. The design and development process is also refocused to incorporate local people throughout stages of the design creating a resonance between foreign and indigenous knowledge in every step of the process. This allows space for any idea proposed by outsiders, but still retains decision-making power within the vulnerable community. This means that technology needs to be the embodiment of external-internal intentional development for improving present immanent development, and seamless integration of the technology to local routines has to be the central importance for any future internal intentional developments. Furthermore, these developments must be based on the changing local circumstances, social goals, and advancements of local people's capabilities. Then, the repurposing and refocusing of technology design and development provides a concrete framework for both foreign partners and the members of a specific vulnerable community.

II.4 Technology in societal transformation of developing area

II.4.1 Acceptance: Challenging community, preventing cornucopia

The first critical issue in the paradigm shift to empowerment-based technologic changes is technology acceptance of the members of a targeted vulnerable community to a technological solution. Also, technology acceptance is very dependent to the form of technology design and development process in incorporating local needs to the process. Some cases in Sub-Sahara Africa (Dunmade, 2002) have shown that many foreign technologies require an early assessment before they are implemented in developing economies, or in other words: vulnerable communities, as a means to assess technology acceptance based on both technology design and development process and existing local condition in accepting a new technology. Such kind of assessment is critical in preventing the domino effects of failures in a technological advancement. In fact, many development-based technological investments have to be abandoned even if the establishment has not been completed. An extreme example of the condition had ever occurred in several populous developing countries such as China (DeFilippo, 1997), India (Todd and Simpson, 1986), and Brazil (Baranson, 1978), including later emerging economics such as Indonesia (Raillon, 1990). Even if those countries are four of few respected developing ones due to the rapid growing of economic power, Steenhuis and De Bruijn (2001) noted that while China have successfully captured some concepts of aircraft technologies to their strategic industries, India and Brazil required longer time to include sophisticated technologies into their technological concepts. On the contrary, Indonesia met many difficulties in their societal transformation regarding the establishment of aircraft industry and finished with big financial as well as societal losses (Amir, 2013). The above cases show an absolute evidence in which technological changes always become crucial challenges to vulnerable communities due to their technology acceptance. Although high technologies have amazing technical specifications, diverse results of technological changes between different social environments underline a necessity in which any technology must always be in conformity to local manners and matters. On the other hand, a vulnerable community with a high technology acceptance doesn't mean that the members will accept any technology and be transformed from a developing into a developed community forever. Many cases have also suggested that cornucopia of technologies will certainly destroy community foundations such as unity or economic power as well as environmental conditions through many disasters, or in development term: the decline of development (Figure II.2, D_{dec}), despite the resilience of those fundamental factors (Manion and Evan, 2002). Those impacts of technological cornucopia occur as the result of careless attention on the technology acceptance of a targeted vulnerable community, meaning that there is a must to conduct the shift to empowerment paradigm. Even if development-based technological changes can perform at an amazing level of advancement, these given technologies are always lurking to turn into disasters when the process doesn't consider technology acceptance of a society or community as a means to extend their resilience by consistently eradicating their own vulnerabilities through the changes.

The above explanations emphasize an important notion in which technology acceptance is not as simple as the idea of technology transfer. While technology transfer forces community members to receive as many technologies as given solutions, the understandings of technology acceptance reverse the presumption to see the term "transfer" as the matching point between technology design and development and societal requirements (Figure II.7), then technological changes and societal transformation (Willoughby, 1990; Bruun and Mefford, 1996; Wicklein, 1998, Rip and Kemp, 1998). Also, technology acceptance has become more important due to the shift of delegated power in conducting technology design and development in the pursuit of continuous local technological changes. It means that through empowerment as the paradigm, technology design and development as the technological-based intentional development will eliminate the barriers of technology acceptance – due to local manners and matters – by producing technological solutions with high technological appropriateness to real community needs and circumstances; hence the oscillations between internal immanent and intentional development can be maintained by the members of a specific vulnerable community themselves through the eradication of their vulnerabilities as the result of empowerment-based technological changes.

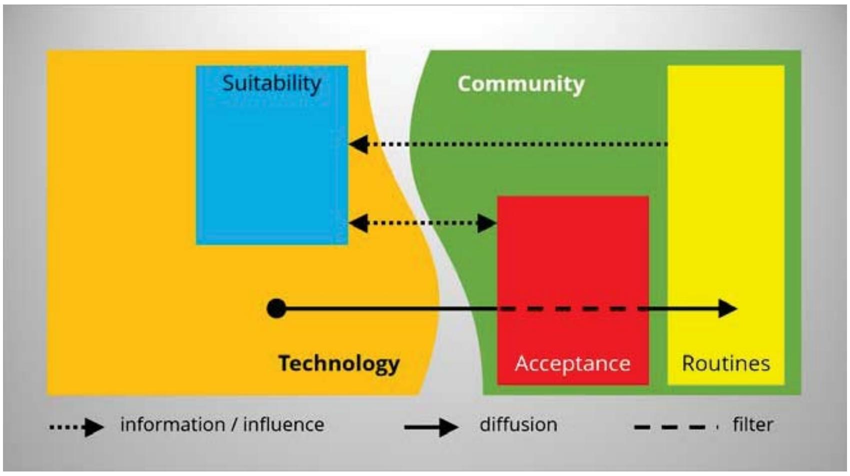


Figure II.7. Technology acceptance, suitability and diffusion.

Furthermore, any effort to ensure the appropriateness of a technology must not be interpreted only by simplifying an existing technological solution to be a low level technology. It is due to the differences between the technology acceptance level of a vulnerable community and the levels of other communities, including the extent to which a technology can be seamlessly integrated to the immanent development of a specific vulnerable community. Moreover, technology acceptance level of a community will change due to continuous internal intentional developments following the shift to empowerment paradigm. It means technological change itself needs to be transformed to maintain the support to the next level of development. Emerging new challenges in the next immanent development after an internal intervention, therefore, will be the basis of classification of technological changes into several steps. In other words, adequate changes based on new challenges ought to ensure technology suitability and diffusion to the next level of immanent development as the product of empowerment-based intentional development. Thus, distinguishing adequate changes in different level of development needs to be planned as community's own strategy to maintain the oscillations between immanent and intentional development without being trapped in technology cornucopia.

II.4.2 Technology suitability and diffusion: Micro to macro changes

In the previous discussion, the shift from development to empowerment paradigm emphasizes the delegation of power from foreign parties with higher bargaining power to the members of a targeted vulnerable community as the subject in doing autonomous development (changes), in which foreign knowledge and power are posited as assistances to trigger the first intentional development and then be revoked over time (Figure II.3, Figure II.4, Figure II.5). In order to do that, technology must be designed and developed in conformity with existing capabilities and abilities of local people (Okejiri, 2000) and diffused into the daily routines of community members (Dunmade, 2002; Weick and Walchli, 2002). While technology acceptance is posited on the people-side, technology-side requires technology suitability in which a technology is continuously redesigned and redevelopment to capture requirements of a specific vulnerable community, including future societal changes that are followed by new forms of technological changes based on any new kind of challenges in the next levels of development, by which a technology is then diffused into local activities (Figure II.7). On the other hand, in terms of technological changes as innovations Rogers (1995) proposed a simple understanding on the suitability of technological changes to overcome high rebuttals and potential controversies around a technology diffusion. He stated that there are at least five factors which determine the rate of technology diffusion: (1).

Relative social and economic advantage; (2) Compatibility with existing values; (3) Complexity of the idea; (4) Divisibility; and (5) Observability. The first factor focuses on relative advantages offered to the members of a specific community regarding any potential improvement of their products and service improvement for their customers due to the implementation of a technological innovation. Next, the second factor underlines the compatibility of a technology to existing values that must be embedded in any innovation, meaning that a technological change should not ruin existing daily routines but can be understood by and is consistent with existing values such as cultural beliefs as well as past experiences of local community members. After that, the third factor expects that a diffused technology should not too far complex compared to existing capabilities and abilities. The fourth factor, divisibility, addresses that an innovation has to be able to be applied in a very limited circumstance and be easily operated by local people. Then, observability means that any result produced by an innovation must be easily communicated and observed to the other members of a community via formal as well as informal ways as a means to trigger broader applications.

Looking at the concept of technology and its relations to the dynamics of societal changes, Rip and Kemp (1998) stated that there is a parallel connection between technology and societal transformation. The connection can be revealed from his previous work (Rip, 1995) in which it is discovered by using the perspective of regime concept. Their concept started from three steps of changes, namely micro, meso, and macro. The names micro to macro refer to the number of driven changes in a supervised society in each respective level, and the position of technology in changing the direction of societal transformation. In other words, macro in Rip's concept can be stated as a technological push, meaning that technological advancements come before societal transformation to which technology direct its purpose to push transformation forward. On the contrary, micro drives smaller numbers of changes in a supervised society, meaning that technological advancements are posited after societal changes to pull the transformation forward. An important understanding which must be carefully taken from such concept is that it is founded of regime concept and focused on robust technologies, meaning that it is a development-based position of technological changes to societal transformation with which a technological regime is driven by interests of the power holders – parties with higher bargaining strength – in a regime. In the paradigm shift from development to empowerment, the parallel connection between technology and societal transformation to ensure the suitability of a technology and its diffusion into local routines requires counter understandings of the regime concept. In that spirit, in term of technological changes in vulnerable communities any change should be started from micro changes due to the less standardized and less structured community, and because of the shift of position of local people from the object of development to be the subject of empowerment, including the basis understanding of empowerment as a bottom-up approach.

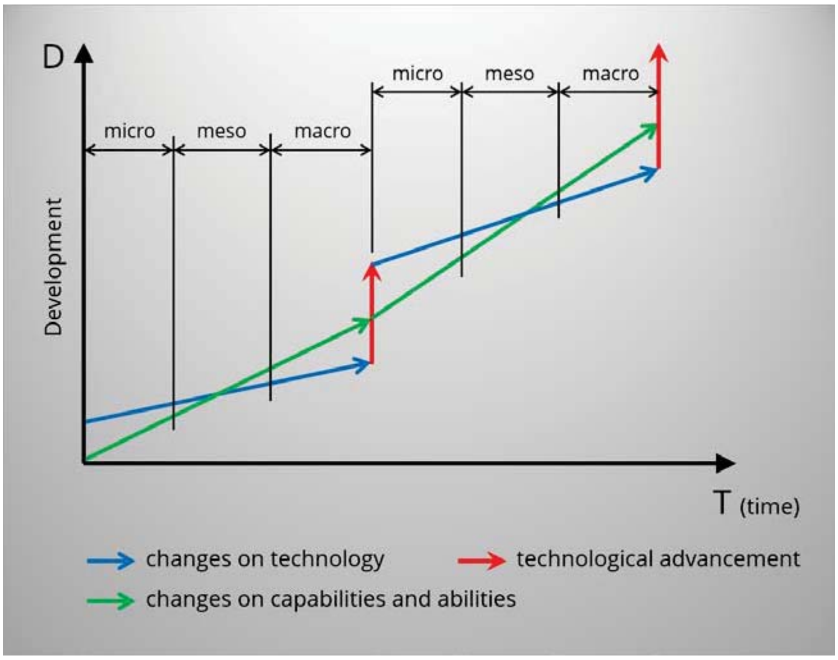


Figure II.8. Micro to macro changes.

Micro step based on empowerment paradigm starts from technology introduction with strong suitability to existing capabilities and abilities of local people into the concept of a technology. The term “micro” means that technological change should be implemented in a less complex system that requires strong assistances from foreign partners, or local assistances from local people themselves, governments, or NGOs. In other words, there are only “micro” changes occur regarding technological capabilities of a specific vulnerable community. In micro step, technological change is posited to lift fundamental factors of local process as the early result of an intentional development (technological advancement). Micro changes attempt to produce a technology only to improve a targeted local process until the extent to which a technological change has produced a stable circumstance and ready to eradicate more vulnerabilities in the next step of changes. In such understanding, micro step is stated as technological push in which the term “push” is the position of a technology as the stimulus of existing local capabilities and abilities (Figure II.8), meaning that technological change stands in the beginning of understandings to eradicate local vulnerabilities in micro level.

After that, the next step, meso, stimulates more opportunities for the members of a specific vulnerable community to capture technological changes in improving their technological capabilities and abilities. It starts after micro step by which improvement of local process has reached a stability, meaning that in meso step local people have a bigger space to pay more attention to eradicate their own vulnerabilities. In meso step, suitability of a technology is amended as capabilities and abilities of local people have been improved due to the eradication of vulnerabilities. A technology is reconfigured in term of numbers in parallel with the change of people’s motivation in applying technology to further improve the result of stable-improved local process. Complexity is also increased due to meso changes in community’s technological capabilities and abilities. More complexity means more opportunities to achieve better results, including faster and better ways to increase scales through multiplied process due to the use of a better technology. In such understandings, a technological change is posited to be in parallel with the further improvement of fundamental factors of local process. The parallel connection is needed to ensure the use of a technology in longer time by community members. In short, meso step is stated as the technological parallels, meaning that changes of local capabilities and abilities are moving forward to be in parallel with technological change (Figure II.8).

Then, macro as the last step starts after the parallel connection is going to be revoked due to substantial improvement of those capabilities and abilities in a specific vulnerable community, meaning that their capabilities and abilities begin to significantly surpass technological change itself. In this step, the suitability of a technology begins to incorporate a new level of technological change: quality. While in meso step a technology is reconfigured in terms of quantity, in macro step a technology is reconfigured in term of its basic specification to be able to produce further multiplication of the quality of local circumstances, so the eradication of local vulnerabilities is reaching its peak in a single cycle of immanent development as the result of the substantial improvement. This requires a technology that is significantly reconfigured to be suitable to fulfill local people's preferences in using a technology in their routines. In this step, the members of a vulnerable community are able to do their own technology reconfiguration to maintain the diffusion of the respective technology. Complexity of a technology, therefore, reaches its ultimate level in its respective immanent development cycle. Involvements of community members are deeply applied, and any partner of local people must significantly decrease its assistances. In sum, technological change in this step is posited as technological pull, meaning that it goes after the improvement of technological capabilities and abilities of community members in macro level as a means to sustain the grace period of a technology through significant reconfiguration of the technology by community members themselves. The macro step ends when the reconfiguration process reaches the limit of a technology, meaning that there is a required major changes on the technology. In such condition, the members of a vulnerable community will conduct next intentional development by doing another technological advancement through technology redesign and redevelopment (Figure II.8). Thus, the next intentional development will indicate the beginning of next micro changes in the next immanent development.

II.5 Rethinking Appropriate Technology

II.5.1 Revisiting history: Eastern technological independence

Understanding technological changes for vulnerability eradication in vulnerable communities in any developing countries cannot be detached from the history of those countries in the pursuit of technological independence after achieving their national independence. In the 1960s, Africans and Asians entered the decades of independence (Edoho, 2009). In addition to the growing needs as a result of their newfound autonomy, developing countries attempted to find sufficient ways to solve the problems emerging among vulnerable communities in their jurisdiction. As the moral obligation after long colonialism, positive missions from developed countries attempted to redevelop good partnerships with developing and Third World countries. As a result, the collaboration introduced the idea of community development. Efforts were then undertaken in later missions to introduce the idea of empowerment. The shift from the development paradigm to the empowerment paradigm has shown that empowerment should be treated as the right way in guiding community transformation process (Wilson, 1996; Lacy, 2000; Cummings, 2001; Diaz-Puente *et al.*, 2009; Ferguson, 2010). After achieving their independence, developing/Third World countries, in association with their partners, also attempted to develop sufficient technology for the processing of materials sources left by colonialism. This was caused by the facts that developing/Third World countries wanted to obtain faster results than ones that would only be possible by using their limited knowledge, which is an effect caused by the long-term colonialism. They also required technology to multiply the result of their transformation process. As a result, developing and Third World countries were quite concerned with the development of sufficient technologies based on their economic limitations (Bourrieres, 1979; Harrison, 1980; Wicklein, 1998). However, problems still arose as the result of technological changes in a low-knowledge community (Teitel, 1978; Narayana, 2003). These problems were caused by many limitations in the local communities, *i.e.* technical, economic, and/or social aspects (Sianipar *et al.*, 2013b). Those barriers were then exert overwhelming effects. Any limitation has its own characteristics but also affects the other ones due to the unstructured nature of the system in vulnerable communities in any developing countries.

At the time, some ideas were proposed to solve such condition. There were ongoing suggestions to balancing scientific technology development from Western and the conscience of local communities. In that spirit, some correlations were proposed to coupe with many ideas surrounding community empowerment, as stated by Kaplinsky (1990) and Sianipar *et al.* (2013a), through the idea of technological appropriateness in particular context and timeframe of each of targeted community. As a means for improving the indigenous knowledge in doing local processing activities, technical consideration is interpreted by how local people can use, maintain, and make a technology by themselves, even if using limited resources. Following the spirit of national independence, such considerations provide the locals with opportunities to initiate technological appropriateness based on their own conditions and to avoid a significant amount of foreign forces from outsiders. Such understanding was then taken as the basis of technological appropriateness. Next, economics aspect, as the common issue in any vulnerable community in any developing countries, was becoming another basic consideration in technological independence. By understanding local economic limitations, technologies need to deliver real economic benefits beside common economic outputs such as profit or cash money. Complete economic calculations, therefore, has to provide more prosperities for locals. It is better than only an amount of money with no clear velocity or purpose. After that, environmental aspect (Yanful, 2009) is also considered as a means to support increasing concerns on environmental issues. Even though it is largely approached by using technical knowledge, its merit is distinctly different from other kinds of consideration. Thus, it is interpreted as the environmental effects imposed by a technology throughout its life-cycle, *i.e.* all environmental impacts imposed by a technology to surrounding environment – which also affects present and future people's health – from its initial sketch to its disposal. Then, some social considerations refer to the seamless integration of a technology to the existing social activities. It is recognized as the ultimate level of technological independence. The support of an autonomous self-reinforcing process is preferred due to the limited knowledge associated with this type of decision making. In some cases, this is interpreted as the technological acceptance level from the local people to a technology (Fritsch and Gallimore, 2007).

II.5.2 Comparing and contrasting AT concepts

At almost the same time as the growing independence of Eastern countries, the thoughts of AT (Table 1) had been increasingly seen as having an important position in such discourse alongside the concerns on technological changes in the empowerment of vulnerable communities. The initiation was first started by a famous sage from the eastern world, Mahatma Gandhi, long time before today's high-technology era. As highlighted by Schumacher (1973), Gandhi stated that mass production is characterized by many activities that are destructive to human life; thus, the answer was provided by reverse production, which is "production by mass." This was similar to the writings by Willoughby (1990, p.118) and Lin and Zhang (2009), who noted that the World Bank even needed to choose between heavy investments in mass production or the maintenance of investments at lower per capita, which affects more people in Third World countries. Although Gandhi's words were strongly influenced by his struggle to achieve a self-empowered society against western colonialism (Ganguly and Docker, 2007), the words were continuously spread around the world. First captured by Schumacher, Gandhi's words became the foundation of what we know today as "appropriate technology." During the past four decades, the thoughts have been developed into a broad definition of appropriateness. Of the many proposed concepts, several are mostly respected by other technologists (Table 1). One of the first responses to Schumacher's proposal originated from Morawetz (1974), who proposed a more specific meaning of Gandhi's idea into a balanced condition between the academic world and its implementation among society. The localization of resources using intelligent methods to achieve social welfare originated from his thoughts. Four years later, Dunn (1978) thought that the idea of 'production by mass' must be adapted as holistic efforts to achieve a self-reinforcing condition to thus adapt society's development path under dynamic conditions. This is characterized by an increase in the wealth and skills of the society's members, which indicates that they can achieve a higher technical system in the future. A year later, the phrase 'appropriate technology' was suggested by Pellegrini (1979) to broaden the meaning from only one piece of a 'technological bridge' into any efforts that include socio-cultural aspects in a technological innovation. Until the late 20th century, many authors had agreed that an AT must not be limited only to the efforts associated with the localization of the required resources, the exploration of the chances of using renewable energy, and/or the provision of new job opportunities but should be characterized as a compact package of technology with affordable prices, preferably small-scale as a result of the targeted community, associated with a careful decision regarding the utilization of scarce natural resources, able to be fused into existing infrastructures, and with required maintenance capabilities that are as low as possible to achieve sustainability (Dunn, 1978; Jequier and Blanc, 1983; Darrow and Saxenian, 1986; Carley and Christie, 1993; Todaro, 1997; Hazeltine and Bull, 1999).

Table II.1. The early thoughts on AT

Definitions	Focuses
Appropriate technology is an effort which consists of fully careful and intelligent techniques in a given environment to use available resource optimally. It also maximizes social welfare while products their factors are shadow priced in specific process and project (Morawetz, 1974).	• available resources • given environment • social welfare
An appropriate technology is any technological effort which creates internal self-reinforcing process among local community members, sustaining their local activities growth, and help the whole community to develop their indigenous knowledges by themselves (Pellegrini, 1979).	• self-reinforcing process • sustaining local activities • develop indigenous knowledges
Appropriateness of a technology is a condition while it engages local people as they are in its development: their existing technical and financial conditions along with their efforts to improve both conditions. The technology should also consider existing manpower supply. Technology transfer process must support strive efforts to improve their conditions so they can reach the required level to produce the best results of technology implementation (Bourrieres, 1979).	• technical and financial conditions • existing manpower supply • technology transfer
Appropriate technologies are intensive in terms of using locally available resources. They also small-scale but efficient in small production units. Appropriate technologies must give benefit for local community and compatible with their socio-culture environments (Thormann, 1979).	• locally available resources • small production units • socio-culture environments
Any technological solution which ensure the use of country's natural resources in economic level and its proportions to the national as well as social goals, and also to the condition of national capital, labor, and human skills. Encouraging appropriate technology means encourage the right technology choice consciously, not only	• economies of scale of natural resources • proportions between national and social goals • national capital, labor and human skills conditions

allowing commercial party(s) to decide the final actions (Harrison, 1980).	
Appropriate technology is a generic term for technological efforts which are recognized through one or more following basic ideas: low investment, low price, takes local socio-culture context into account, expand potential employment, easy to be managed and organized, sparing dan careful use of natural resources (Jequier and Blanc, 1983).	• low investment and price • takes local socio-culture context into account • expand potential employment • easy to manage and organize • sparing and careful use of natural resources
Provides technologically appropriate efforts which are fit to the local economic structures: community capability to manage themself, ability to operate and maintain their facilities, to finance their activities, and to conserve their environmental conditions (Betz *et al.*, 1984).	Local economic structures: • management capabilities • operation and maintenance ability • financial ability • environmental conditions

While the development of AT thoughts until the end of 1980s was focused on the specific-characteristics of an “appropriate” technology, since the beginning of 1990s the focus was largely shifted to a more general-principles (Table 2) (Willoughby, 1990). Started by Willoughby himself, the understandings of why does one state that a technology is appropriate began to give a larger portion on the particularity of a technological solution regarding its placement and timeframe of usage. The contexts included biophysical (tangible) and psychosocial (intangible), meaning that a technology would become a significant solution if and only if it has considered particular conditions in supporting local growth. After Willoughby’s proposal, Sclove (1995) attempted to correlate technology and the ideology of democracy. He stated that technology choice is dependent to political values applicable in a particular region. His thought was then taken as an important positioning in the pursuit of technological independence for vulnerability eradication in many developing countries. In the discourse of AT amongst AT thinkers and practitioners, following Willoughby’s and Sclove’s thoughts there was Todaro (1997), an economist who proposed the particularity of an AT at individual and/or communal levels by considering existing and potential changes of social and political constructs in a specific region. After the shift of understandings in 1990s, in the 21st century AT thoughts have been becoming to be more referred as a general-integrated approach rather than only a device with specific specifications. Akubue (2000) refers AT as a developmental approach, meaning that AT is an integral part of local problem solving that empowers local capabilities and resources. Such proposal goes beyond common understanding of a technology for job creation or exploitation of existing resources. After that, Wajcman (2006) takes a more feminist position by suggesting a deeper position of technological solution to local daily routines. Social contexts in a specific location then become a critical consideration in his understanding, and have to be considered in technology development as a means to put technology as a local solution. Next, Lucena *et al.* (2010) begins their proposal by highlighting 21st century's global concerns on environmental issues throughout related activities of a technological solution. Besides social impacts, technology development needs to pay enough attention on potential impacts imposed by AT-related activities in the frame of continuous interactions between the members of specific community to surrounding nature. Then, the second decade of this century marks the next shift of AT thoughts. Following a remarkable notion by Kaplinsky (2011), Sianipar *et al.* (2013b) suggests the meaning of technological appropriateness based on a deeper understanding on the practicalities of its concept, intermediating specific-characteristics of an "appropriate" technology to the general-principles of technological "appropriateness", hence emphasizing both strong conceptual and practical levels. They propose the levels of appropriateness stated as basically (technical and economic), environmentally, and socially (cultural, judicial, and political) appropriate, as a means to give a clearer view on the resonances between a specific technology to contextual matters in a specific location.

Table II.2. Thoughts on AT since 1990s

Definitions	Focuses
A technology custom-made to be suitable with biophysical and psychosocial contexts central in a particular area and timeframe. It underlines the universal significance of redefining technological appropriateness in respective set of situations (Kaplinsky, 1990)	• biophysical context • psychosocial context • particular location and timeframe
Appropriate technology is an integrally socio-political construct. Technology is an embodiment and expression of political value choices that, in practical, are mandatory at individual and communal levels through political mediums or elsewhere (Sclove, 1995)	• social and political constructs • individual/communal levels
A technology has to be appropriate with existing factor legacies, *i.e.*, a technology that takes relatively smaller labor proportions into account compared to other factors in a labor-intensive economy is less appropriate than one which employes a relatively higher proportion (Todaro, 1997)	• appropriate to existing circumstances
Appropriate technology refers to a developmental approach which empowers local capabilities development of existing skills to increase community productivity by going beyond job creation and resources exploitation (Akubue, 2000)	• empowering local capabilities and resources • community productivity
Appropriate technology has to reflect the routines of local people by incorporating existing social context in which it is developed into consideration in technology development (Wajcman, 2006)	• existing routines • social context • local considerations
Appropriate technology is a technological solution designed to fit with local settings and communities through stronger consideration on social and environmental impacts by redefining the interaction between communities and nature (Lucena *et al.*, 2010)	• local settings • social impacts • environmental impacts • interaction between communities and nature

Technological appropriateness is the main strength of AT. It can be technically, economically, environmentally, or socially appropriate. Any of those types underline the idea of how a technology can resonance the facets of humanity (Sianipar *et al.*, 2013b)	Technological appropriateness • technical • economic • environment • social

II.5.3 Critics to Appropriate Technology

However, similarly to many other great ideas, debates always emerge with the development of ATs. One of the first notable strikes to ATs occurred a few years after Schumacher's proposal. Rosenbrock (1979) commented on how people understand technological appropriateness. Because the term AT starts with the debatable word 'appropriate', critics argued that an AT can only be implemented at the time when it was designed. The origins of AT, which originated from Eastern wisdom, were also noted by the Western World, which tended to claim that their own technology will always be too far advanced to be dominated by ATs. This was most likely caused by the reality, which Willoughby (1990) and Kaplinsky (1990) had noted, that the Western countries need to maintain their dominance over the developing and Third-World countries, both in technology inventions and in socio-economic power. Furthermore, the Western countries' critics included sophisticated technologists and Western economic activists (Pursell, 1993). Based on the power of the knowledge-based movement, their statements strongly encouraged standing against the development of ATs (Hazeltine and Bull, 1999; Thormann, 1979; Brooks, 1980). Western countries tend to state that the appropriateness of a technology will decrease the possibility of obtaining an improved solution for society. Thus, the choice of a worse solution for implementation in the field would result in a very vulnerable condition. Inefficiency and the inability to achieve real societal growth have also become hot topics because "appropriateness" would lead to the adjustments and compromises of many developmental factors. From an engineering standpoint, ATs are considered failed products due to their insufficiency to fulfil scientific requirements. However, despite the facts that the critics exhibit a strong influence worldwide, ATs are continuously moving beyond their criticisms. The opposite opinions, which claimed that these technologies originated from field evidence (Bhagavan, 1979; Rybczynski, 1982; Sampat, 1995), could not avoid the facts that their judges were picked up from allegations. Their understanding that ATs cannot provide the best solutions was easily contradicted by evidence that an AT is really the best solution under certain conditions. This also means that an AT will provide real development to its targeted community. In spite of their adherence to engineering expertise, the critics should admit that it is easier to use an AT as an intermediate technology (Hazeltine and Bull, 1999) rather than forcing a community to accept sophisticated technology from developed countries. In the 21st century, the critics are still stood but in different form. Kaplinsky (2011) stated that ATs need to shift its non-for-profit position to become a for-profit solution for private firms by producing "appropriate" technology to be sold to communities. In such understanding, AT is criticized to have critical ignorance to potential adaptation for products from developed countries to be more affordable for people in many developing countries. His suggestion is also supported by James (2014). In spite of his direct critics to Kaplinsky's writing, James supports the basic understanding of Kaplinsky's idea in which AT could be a powerful solution for private firms in many developing countries. However, it has to be noted that the understanding of "appropriate" technology has been shifted from only a product/device to a solution-based approach for vulnerability eradication in a specific developing country. The members of a specific vulnerable community, therefore, are not a market for private firms, or in other words: object of development. Community in technological problem solving is the subject that drives the development of a technology for their own interests and not for parties with higher bargaining power such as private firms. Then, as technologies become more widely implemented for vulnerability eradication in many developing countries, ATs have firmly declared themselves to be a powerful approach, even if it is applied for locations with too many local constraints, by delivering its strongest and only weapon: the powerful ‘appropriateness’.

II.6 Towards the appropriateness of a technology

II.6.1 Mainstream development of design in engineering

In the pursuit of technological appropriateness of a designed technology, engineers have exerted many efforts in recent decades. Ironically, their efforts had been hardly grappled over time without being sufficiently noticed. Starting approximately five decades ago, industrial and military engineers began to exert efforts in technological adaptation (Lucena *et al.*, 2010). At that time, adaptation meant that the local context shall be taken into account in technological development. The movement was based on previous engineering experiences that tended to overlook indigenous knowledge of each local community, including its autonomous nature and self-supporting traits. The negligence was favored due to the technological battles in the Cold War that spread the superpowers’ influences between the US and the USSR (Mitchell, 1988; Moore, 1994). The increasing battle tension affected the engineers who were pressured to exploit many resources for modernization purposes, such as industrialization and economic capitalization. As a result, indicators of societal improvement were only associated with technological and economic perspectives at the macro level, yet the micro-scale economics, the community’s societal subsistence, and the environmental impacts were disregarded. The legacies of colonialism, which have existed for a long time, have transformed the mainstream technological and economic exploitations that directed all of the engineering perfections in the following decades, even after developing countries had achieved their independence for a long time.

In the wake of the independence of countries in Southern hemisphere, engineers became a vital part of the national stakeholders. Because almost all of the knowledge left by the previous administrative governance(s) were held by engineers, these individuals participated as the transitional bridges for their newborn countries to rebuild all aspects of life and governance. Following an overwhelming cheeriness due to their independence, new governments of developing countries attempted to evade any re-entrance of colonialism by tightening the national involvement throughout their jurisdictions. To strengthen their abilities to meet their own needs, new governments aimed to localize the resource distribution and to achieve equitable development for all citizens. The communities were pulled out from their existences in bounded origins to become a single union with a national government that claims to control their area. Referring national resilience as the reason, communities were brought into an integrated process of development. However, many of technocrats at the time (most were engineers) had a comprehension of the meaning of national development that was very similar to one that was held by the previous governance(s). This made these individuals the continuation of a directed approach in functional orders. All of the communities returned to being objects rather than being invited to work together as the subjects of their own development process. Communities were always ignored as stakeholders and treated only as the national labor to support the construction of infrastructures and/or labor in the name of national productivity.

Following these phenomena, some engineers began to search for a new meaning of technological appropriateness. They started to understand the needs of communities in their new countries and figured out that their communities lacked their basic needs (Rist, 2002). Based on their observations, the engineers attempted to build understandable meanings of technological appropriateness to meet the communities' demands. They interpreted the communities' basic needs into parameters that can be fulfilled by technological improvements. They then attempted to convert these needs into technical parameters to fulfil them using their engineering knowledge. Using the limited knowledge left by colonialism, the engineers tended to grasp the local knowledge of communities in a mechanistic way. They thought that any implementation of technologies could be comprehended in a universal way, regardless of the time and place. The fulfilment of the communities' basic needs was still conceived as a way to consolidate the communities as an integral part of the national economy. Due to the limited and complicated control that each new government exerted in its communities, the existence of each community was still observed in the exact same way as the other communities in each newborn country. Technological appropriateness was concluded based only on their basic needs. As the result, the basic needs of the communities were lacking. The communities could not go beyond their existing conditions because they were treated only as objects. Their futures were decided as a single national purpose, regardless of the social goals of each community.

Moreover, the internationalization of the economy since the 1980s had abandoned any efforts to pursue technological appropriateness for local communities (Lucena *et al.*, 2010). The "threats" to developed countries from emerging economies at the time, such as Japan and/or China, brought attention to communities that were far from the engineering mainstream. Technological developments were concentrated on large-scale projects, such as metal foundries and large-capacity electricity generators. Efforts for the fulfilment of vulnerable communities' needs were diverted to technological improvements due to the national concern in gaining international competitiveness. In almost all developing countries, where vulnerable communities mostly exist, the communities were affected as their countries began to enter free markets. Due to previous development efforts by local engineers, which did not develop these communities to become sufficiently competitive, the communities must enter an unequal competition between countries. They were disempowered due to the inability of their country to compete in the international market. Their basic needs were then even diminished because they were previously forced to be involved in the country's integration efforts. The communities were then regarded as barriers and obstacles to the country's competitiveness. Engineers then treated them as burdens due to their ineffective and inefficient workings, including low level knowledge, which, ironically, the communities had obtained from local engineers. They were then forced to become part of the international competition, regardless of their social goals and self-reinforcement natures. They were even coerced to exploit their own area for natural resources and/or be employed in manufacturing activities by leaving the indigenous daily routines that had allowed them to survive for centuries.

II.6.2 The big hole: Engineering design for AT

After much diversion, engineers began to understand that they could not achieve real vulnerability eradication for vulnerable communities in many developing countries through technological changes if they did not address the root of the problems on their own side. In the late 19^{th} century, engineers began to overcome their own problems from the beginning of any process: design. Design, as any of other processes, affects the result of a technological development observed by the targeted users. However, design has a more fundamental effect on the whole development, including the users of a technology. It produces a framework wherein a technology will be used and sustained among its users. It results in the foundation of a technology based on certain circumstances (Pearson, 2006; Young, 2010). At that time, engineers began to refocus their attention to not the products but the design process itself. They engineered their design process to change the behavior of design process based the specific-characteristics and general-principles of technological appropriateness. Based on similar movements in industrial sectors (Cross, 1984; Pahl and Beitz, 1984; Bayazit, 2004; Pahl *et al.*, 2007), engineers who exhibited concern for communities aimed to obtain an appropriate design processes that would construct substantial technological appropriateness to any technologies designed for a specific community. By targeting the beginning of any process, engineers expected to transform the complete design approach from an industrial-based approach, which focused on mechanistic efficiency, into a community-based approach that aims to produce adaptive technologies based on local conditions (Figure II.9).

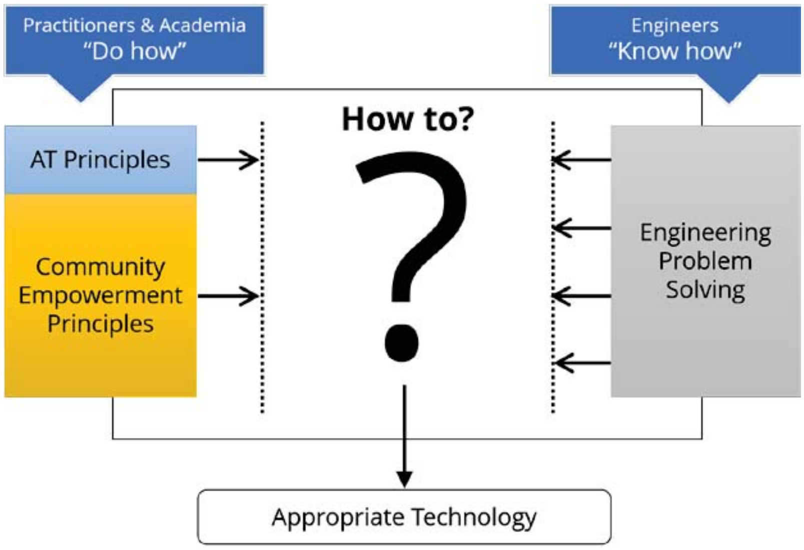


Figure II.9. The Big Hole (Sianipar *et al.*, 2013).

However, as stated by Riley (2008), engineers had already stay stood on their engineering approach so-called EPS (Engineering Problem Solving). In order to design a technology, they had made EPS as a strategic thinking to solve all engineering problems. They picked field problems as a set of inputs for product design and then engineer their design process to fit with an objective function of the process. Their inputs might be given by other multidisciplinary perspectives to give complete overview of the objective function. After they get the inputs, they did separate activities to process the inputs. Some approaches had already included simultaneous involvement of other disciplines into design process, but engineers became the main conductor of design process and the other parties mostly did check-and-balance activities to the process. In short, engineers stood on the closed-engineering standpoint. Problems were given to be solved, involvements are limited on check-and-balance matters. On the other hand, both practitioners as well as academia in AT and community development area had already provided many characteristics of technological appropriateness as the basis of AT development (Lucena, *et al.*, 2010). They also gave notions on how community empowerment should be conducted, and explained critical issues surrounding their efforts. They knew what should be done or not, and they understood that community development was an inappropriate complex way to solve unique problems in each practical area. These conditions became crucial matters which must be embedded into AT.

However, many field collaborations between engineers and practitioners-academia of either AT or community development were still in doubt due to some reasons (Sianipar *et al.*, 2013c). In those cases, practitioners & academia maintained their viewpoint by stating that any engineering process must be taken together with local people; however, engineers strongly kept EPS as their ultimate standpoint. Such counterintuitive requirements had forced engineers to leave their role as industrialists to be field assistants. Engineers, therefore, were being confused to choose between their preconceived knowledge in defining engineering appropriateness (Sianipar *et al.*, 2014a) and the constructs of technological appropriateness for a targeted community (Sianipar *et al.*, 2013c). In order to make a compromise, engineers attempted to intermediate their pure engineering approach and community's needs. They tried to bring technologies from foreign area and adapted them to local basic appropriateness. Looking at above situation, there was a big hole between engineers and practitioners-academia (Figure II.9). The EPS approach was arguably rigid hence it is troublesome to incorporate both empowerment and AT principles into its workflow.

II.6.3 Design for 'X': The engineering of design process

One of the most notable of these kinds of efforts was proposed in the early 1990s. Preceded by environmental movements that advocated "Design for Environment", including "Design for Environmental Protection" and "Design for Resource Conservation" (Fiksel, 1996; Amstrong, 1997), "Design for Sustainability" emerged as a promising solution at the time. One of the first initiations was performed by engineers through collaboration between academia from Delft University of Technology (TU Delft) and the United Nations (UN) in the form of Ecodesign (Brezet and Hemel, 1997). Ecodesign was proposed as an attempt to provide a design approach that is focused on environmental issues. It embedded environment as the third addressed issue in addition to economic and technical ones. Ecodesign produced some improvements: the so-called eco-label, eco-efficiency, clean product, and cleaner production. These improvements were famous for their emphasis in the pursuit of considerations related to human health and environmental safety (Lee, 2009), even though it had not yet encoded the social aspect thoroughly. Ecodesign was broadly accepted in industrial countries, but it faced many obstacles in many developing countries. Western-accents design was still inappropriate when it was implemented in contextual projects particularly in vulnerable communities in many developing countries. Ecodesign was more inclined to pay attention to "green" issues rather than specific problems in the communities in which it was put into practice (Hawken *et al.*, 1999; Walker, 2002). It focused on a less-extensive use of resources and promised the sustaining of humankind by implementing a more stringent usage and increased care of Earth. However, communities were not affected until the transformation of Ecodesign.

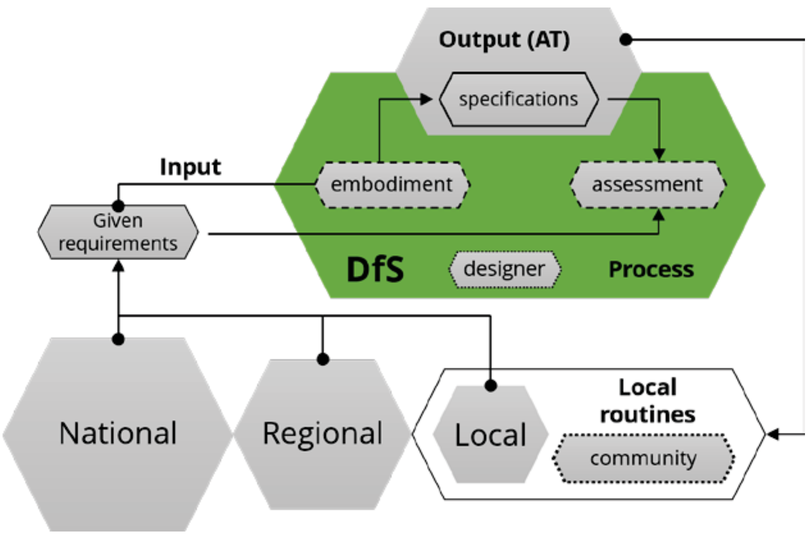


Figure II.10. Design for Sustainability (DfS).

In addition to the increasing attention on the importance of developing countries in the world's constellation, Ecodesign was criticized to address larger attention on social issues (Brezet and Hemel, 1997; Crul, 2003; Boom, 2005). It was pressured to give a proper portion of considerations on local socio-cultural conditions in addition to the technical, economic, and environmental aspects; this led to the evolution of Ecodesign to become "Design for Sustainability" (Figure II.10). This type of design (hereinafter denoted as DfS) was developed in the age of "Engineering to Help" in the 2000s (Lucena *et al.*, 2010). It was proposed by TU Delft in collaboration with the United Nations Environment Programme (UNEP). These researchers attempted to adapt Ecodesign to the conditions in any developing countries by encompassing social aspect as the bridge of technological appropriateness. By including social issues, DfS included all three fundamental principles of sustainability (economics, environment, and social) in the technological development. Furthermore, DfS was not supposed to only focus on the design of technological solutions, but it also proposed how to achieve a certain target of economic growth while simultaneously reducing the contradictive impacts imposed to the environment and social conditions. Thus, it was stated as an effort beyond the "green" issue by pervading a more sustainable approach for the achievement of improvements in many developing economies (Clark, 2009). Then, the DfS program was implemented in many developing countries, such as Latin American, African, and Asian countries. It was implemented as a solution for the encouragement of innovation in an environment with a low degree of engineering expertise. SMEs in many developing countries had successfully proven that DfS was able to achieve its objective (Diehl and Kuipers, 2008; Evrard *et al.*, 2009; Haffmans and Winthagen, 2009). It became the accelerator of innovation in the exploration of sustainable opportunities. With respect to sustainability issues, it has contributed to the growth of supporting economics through a holistically and life-cyclical emphasis in many technological improvements.

However, like previous design approaches, DfS was again trapped. It became an economic-based technical design approach that attempted to include environment and social issues as impacts rather than the main concerns. Engineers remained focused on their previous approach of Engineering Problem Solving (EPS) with its inflexible approaches (Riley, 2008). The later implementations of DfS became demonstrations on how DfS can become a solution for profit-based organizations rather than local communities. In DfS, local communities were treated as the consumers of the technological improvements. Engineers came to a developing country by bringing such technologies and adapting them to the given local conditions, but this resulted in the production of low-level inexpensive technology. DfS became a hard approach (Figure II.10) to the community, which indicates that the engineers treated the social issues as something that "negatively" impacts technological development. In other words, which were rarely admitted by engineers, communities were observed as contributing "negative" impacts that must be reduced. Even if the engineers have aimed to "listen" to the communities' needs, their listening was directed to information gained from communities as the lack thereof. Engineers still treated communities as entities with many discrepancies rather than capacities (Lucena *et al.*, 2010). DfS then became similar to the other approaches that have been previously attempted. It focused on economic growth by implementing new technologies, and the engineers then attempted to consider a reduction of environmental and social impacts to achieve larger opportunities for selling their technologies. Thus, the more-sustained party was business/private firms but not communities. Although some opinions claimed that there was a wealth balance between stakeholders, large technological interventions to the communities' routines in the name of modernization endangered the indigenous knowledge which, as have been previously explained, had survived for centuries without any major human-caused environmental/social issues.

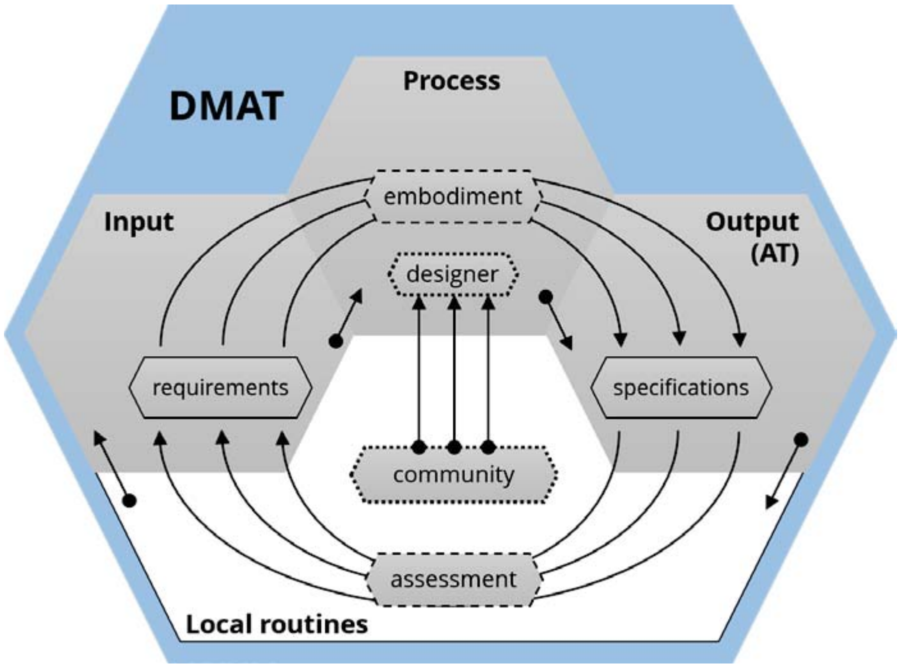


Figure II.11. Design Methodology for Appropriate Technology (DMAT) (Sianipar *et al.*, 2013c).

Those explanations have given a clear notion that the big role in research on technological development in any developing communities still largely open due to the lack of a set of engineering design processes that incorporates substantial AT and community empowerment principles in order to achieve real technological appropriateness of a designed AT (Figure II.9). In order to fill such big hole, *et al.* (2013c) had proposed a new design methodology that is dedicated for designing AT. So-called the Design Methodology for AT (DMAT), it was developed as the guidance for engineers in doing design and development process of AT, from scratch to be a readily-to-use socio-technical artifact. The main idea of DMAT was the integration between bottom-up community problem solving and top-down engineering problem solving approaches (Figure II.11). Design process of an AT was constructed as a set of intercorrelated activities between community members and engineers, oscillated throughout the process to ensure the technological appropriateness of an AT. Some responses to the DMAT indicated that the work had precisely targeted the main concerns of technological development for developing communities: a dedicated design methodology to avoid poor outcomes due to inadequate approach in doing design process. Feinblatt (2013) stated that it is considered as an important and systematic design methodology that is strongly required for designing and developing appropriate technology in the contexts of technical development in any developing communities. Besides, Goodier and Moseson (2013) stated that it is the methodology wherein communities are formally encoded and moved to the center of design process of AT, meaning that the axiom of a human-centered design process has been precisely addressed.

However, there are some limitations in the DMAT. Limitations that become the barriers in both conceptual and practical levels (Goodier and Moseson, 2013). First, there is a clear intention in the whole impression on DMAT to dismiss the value of technological adaptation to developing communities. There is nothing wrong with it; however as previously discussed, technological adaptation must not be ignored due to the fact that it is a common approach in implementing technical advancements in many developing countries (Wiloughby, 1990). Besides, technological adaptation allows any application of AT "to learn from history and contemporaries, and avoids the reinvention of the proverbial wheel" (Goodier and Moseson, 2013). Second, multi-criteria proposed in the ninth step of DMAT has to be put earlier in the process, meaning that there is a need to include some assessments in the beginning of design process to build a stronger foundation of the whole process. Although there is an informal Q&A as the technique to put the foundation of assumptions, engineers from developed countries seem interested to have more contributions since the beginning of design process. The last limitation is the position of social factor both in its concept and practice. As emphasized in the DMAT that social factor is "the ultimate level of technological appropriateness" (Sianipar *et al.*, 2013c), the fact that there is only a few detail to define social factors indicates that such kind of factors needs to be further tweaked and derived into more operationalized understandings. In spite of the proposed idea in which social aspect refers to some more intangible factors such as cultural, judicial and political

(Sianipar *et al.*, 2013b), the specific limitation has indicated that such kind of factors are really getting attention from engineers.

II.7 Research gap and positioning

II.7.1 Technological changes for vulnerability eradication

The increasing uncertainties in today's complex world have shifted attentions of scholars and practitioners to vulnerability-related issues. While discourses on world's worst problems, *i.e.* poverty or environmental hazard, focus on the importance of distinguishing between symptoms and root problems in order to do decision making for taking strategic problem solving, vulnerability-related studies propose a more integrated understanding to put any societal attributes as having reciprocal influences each other, creating a holistic understanding in eradicating vulnerabilities. The term vulnerability itself has an interdisciplinary understanding (Cutter *et al.*, 2003; Turner *et al.*, 2003b) due to those reciprocal influences between fundamental factors in an observed societal group. Furthermore, the critical position of vulnerabilities in exposing a societal group to crises has made concerns on vulnerability eradication to target developing communities (Robards and Alessa, 2004). These kind of communities is recognized as the most critical type of communities that might fall into crises due to the instability of its fundamental factors of survivability. Vulnerabilities critically embedded in a particular community then makes the community to be stated as a vulnerable one.

On the other hand, implementing vulnerability eradication with an additional attention to the particularities of each vulnerable community requires an interdisciplinary solution. In such understanding, technology has emerged as a strong solution to eradicate vulnerabilities directly from interconnected characteristics of a technology to many facets of daily routines of local people (Turner *et al.*, 2003b; Garniati *et al.*, 2013). In addition, particularities in vulnerability eradication has triggered the further potential of AT to be a powerful technological solution. AT itself is an approach for providing a technological solution that is founded on the particularities of addressed problems in a specific area. Its strongest power is stated as technological appropriateness, by which the solution is developed based on local problem solving and matched to specific requirements on field since the earliest stage of technological development. In facts, characteristics of every vulnerable community as a fragile societal entity indicate the need of a technological solution with a strong technological appropriateness to precisely address its vulnerabilities. Furthermore, as vulnerability eradication is considered as a continuous process, there is also a need to apply technological changes. The solution is therefore stated to incorporate technological changes on AT to conduct a sustainable vulnerability eradication. Based on such concerns, recent developments on both technological changes and AT have proposed an important progress toward vulnerability eradication. In technological changes, recent discourses have begun to propose a more sustainable change based on bottom-up approach. Researchers agreed that technology developments need to incorporate global concerns, yet the actions must be local in order to seamlessly diffuse those concerns into local activities. Those understandings are parallel with the development of thoughts on AT. When concerns should be global yet actions are local (Few, 2003; Leichenko and O'Brien, 2002), AT is the right way to do those combination. Recent developments of AT indicate that its concept has been widely recognized in putting technological appropriateness as an ultimate characteristic of any technologies. The concept of AT is hence diffused also into any effort to produce technological solutions for vulnerability eradication. However, those scientific progress – the parallel developments of conceptual thoughts, field researches, and technological solutions that contribute to the evolution of vulnerability eradication over time – are rather discrete than unified. Despite their parallel developments, they require new researches to move the progress toward both unified conceptual understandings and practical actions.

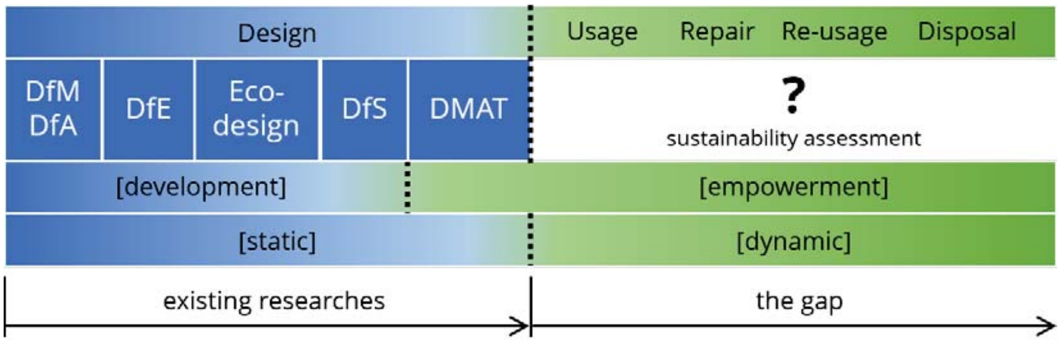


Figure II.12. The research gap: Dynamic assessment.

II.7.2 Research gap: Dynamic assessment below the radar

The scholarly discussions on the paradigm shift in the study of technology, particularly technological changes, for vulnerability eradication in vulnerable communities (Heinen, 1994) have indicated that there is an ongoing progress in scientific communities to put empowerment as the ultimate intention of developmental works (Narayan, 2005; Alsop *et al.*, 2006) (Figure II.12). In such discourse, the intention is to put local people as the subject of development, meaning that they become the main conductor of cyclical developmental progress in their own future. The vulnerability eradication is hence taken as a sustainable process that covers future decisions related to changes on vulnerabilities as the root problem and changes on applied solutions taken in the eradication. Furthermore, when technology, particularly AT, is taken as the solution in vulnerability eradication, the shift of paradigms also affects the focus of technology development (Figure II.12). In the typical development paradigm, technology development is only focused on two matters: how a technology is designed by foreign partner(s) and is introduced to general vulnerable communities. Indeed, technology is seen as merely a product of design process behind-a-closed-door that would be taken as a solution for vulnerability eradication by local people in their local activities. On the other hand, the shift to empowerment paradigm requires an extended focus of technology development to cover more applicative activities such as the usage, local repair, re-usage, and local disposal of an AT. Those four activities are the minimum requirements of observation in understanding the sustainability of a technological solution. Besides, some other particular process, *e.g.* material degradation, trial & error, *etc.*, are possible to be incorporated if necessary. By covering a wider observation, analysis on the sustainable technological appropriateness and predicted changes on vulnerabilities could be conducted through an explicative and more holistic investigation.

While the shift of paradigms is widely discussed in terms of purely conceptual understandings, scientific progress on methodological development is also increasingly interesting for scholarly communities. However, the shift is not devoted to completely replace previous methodologies with a new one. In other words, applied paradigms in different methodologies are rather incremental than absolute, meaning that many newly developed methodologies are intentionally purposed to cover more specific area to refine the coverages, qualities, and characteristics of previous ones. Based on the spirit to refine the coverage of previous "Design for X" methodologies, Eco-design and DfS (Fiksel, 1996; Clark *et al.*, 2009) have initiated a shift towards empowerment-based ones. Despite the critical focus of Eco-design and DfS on environmental issues, there are big parts of their approaches still stand on typical development paradigm. After that, DMAT emerges to clearly bring technology development into a more empowerment-based one (Sianipar *et al.*, 2013c). The purposeful methodology is stated as an important breakthrough to put local people as the subject of development. Therefore, the DMAT could be distinguished to previous methodologies as it stands on empowerment paradigm (Figure II.12). However, either DMAT or DfS and previous ones are strongly focused on design process. In spite of the improved coverage of DfS and DMAT to consider future changes of technology usage and affected prosperity of its users, their focuses are intentionally directed on the design process. Other applicative process are hence posited as additional considerations, yet the investigation takes static calculation on present situations to predict the future.

On the other hand, investigating extended focuses of technology development for vulnerability eradication, including the shift from typical development to empowerment, also requires an extended analysis that covers many possible changes in the future. While present situation changes in the future, addressed vulnerabilities and applied solutions would also change to be in conformity with required actions in each circumstance (Turner *et al.*, 2003b; Turner *et al.*, 2003a; Richmond, 1993; Bagheri and Hjorth, 2007; Hjorth and Bagheri, 2006). Indeed, those changes may happen as several dynamic possibilities depend on some possible scenarios. In fact, those possibilities are parallel to the understanding of shift toward empowerment-based analysis. Scientific progress on pure conceptual discourses and refined focuses on methodological development indicate that the development of a technological solution for vulnerability eradication in a particular vulnerable community ultimately requires dynamic assessment on some possible scenarios which incorporate alternative solutions possibly happen or taken in the future (Figure II.12). In such understanding, the sustainability of both technological solution, particularly AT, and vulnerability eradication determines the resilience of a particular community. In other words, the sustainability of solution and process produces the survivability of targeted societal group. Looking at the existing scientific developments (Figure II.12), there is a lack of research on the dynamic analysis to assess the sustainability of AT and affected prosperities of local people. Therefore, research is required to develop a new assessment framework/tool for conducting dynamic investigation on alternative technological solutions, particularly AT, as a means to understand the dynamic behavior of the solutions in a sustainable manner. The research needs to cover both required focuses based on both development and empowerment with more focus on the later paradigm. Then, the product of the research should be in line with the ongoing scientific progress, meaning that the new dynamic assessment would become an integral part of the existing body of knowledge of technological solution for vulnerability eradication in vulnerable communities.

II.7.3 Research scope and positioning

Based on the research gap, including required research to fill in the gap, several scopes need to be taken as the guidance of analysis. An adequate research scope means that the required research would consist of enriched contents without ignoring the appropriateness of covered boundary. Looking at previous discussions, there are four groups of optional coverages (Figure II.13). The incorporated coverages are then selected among options in each of those groups to indicate the research positioning among available combination of coverages. The first group is the developmental paradigm, consisting aforementioned typical development and empowerment ones. As previously discussed, the selected paradigm is empowerment. In spite of possible coverage on some characteristics of typical development, empowerment paradigm is intentionally selected as the basis of the new dynamic assessment framework to be parallel with recent scientific progress. The purpose is also affected by the concern of putting local people as the subject of development, creating a more survivable societal group with a good resilience.

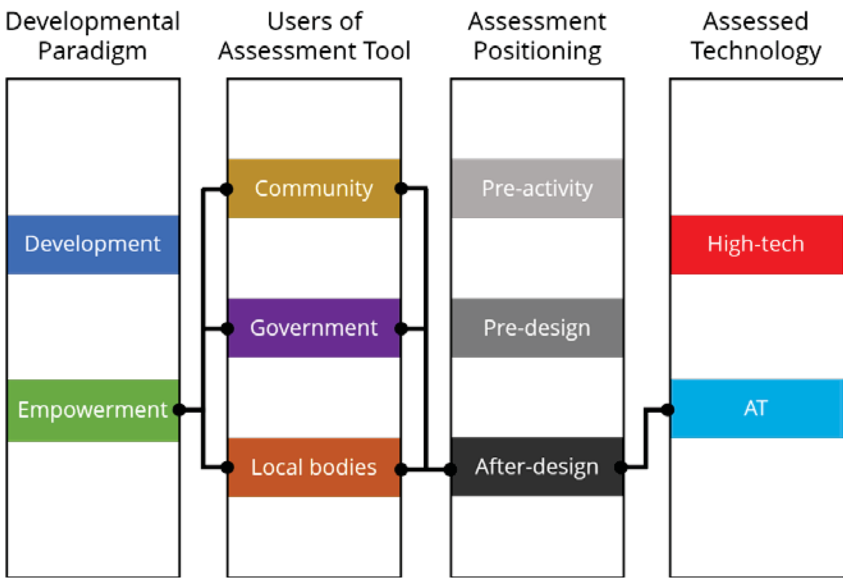


Figure II.13. Research scope and positioning.

Next, the second group is three possible users of the new assessment framework/tool, namely Community, Government, and Local bodies. Considering the usefulness of a dynamic assessment, those three options are selected. For Community, a dynamic assessment means their capability to understand the effects of any proposed ATs on their future prosperity. For Government, assessing alternative technologies through a dynamic analysis is critical to ensure a continuous vulnerability eradication in their jurisdiction. Then, local bodies such as NGOs or association could take the advantage to offer a more holistic assistance for local people. After that, regarding the positioning of assessment process itself (Figure II.13), the option pre-activity means the assessment is taken before the decision of using technology as the solution for eradicating vulnerability. The second option, pre-design, refers to the decision taken to choose existing alternative technologies as the basis of design. Then after design is taken in deciding which AT would be applied among some alternatives. By considering the research gap and the intention of dynamic analysis, assessment is only posited to cover after-design, meaning that dynamic assessment is taken on some alternative technologies that have been designed in order to choose the best design for being applied further. Moreover, the last group indicates the type of technology covered in the research (Figure II.13). The framework/tool is intentionally purposed to assess AT as the technological solution, hence high-tech is not covered by the research.

Chapter III RESEARCH METHODS
Case Study and Approach

III.1 Case study: Cocoa industry in Aceh, Indonesia

III.1.1 Cocoa in the world: Brief history

Cacao (*Theobroma Cacao L.*) has been used to name a small evergreen tree that is known as a native plant within the deep tropical regions in all over American continents, except the northest parts (Coe and Coe, 1996; Hurst *et al.*, 2002). In terms of taxonomic classification, it is included in the family *Malvaceae*, or the mallows, which is a flowering-plant family. At large, the family itself contains 4225 known species with about 244 genera (Christenhusz and Byng, 2016). Within the family, cacao tree is classified under the subfamily *Sterculioidea*, which then belongs to genus *Theobroma* alongside 21 other *Malvaceae* species (Wilkied *et al.*, 2006). As an evergreen plant, it grows green leaves throughout the year. Practically, cocoa tree, as an evergreen plant, does lose its leaves; however, it replaces its ageing leaves not all at once and does so gradually as old leaves fall. Besides, cacao tree is known as a cauliflowery plant, by which its flowers grow directly on its trunks and older branches. As an interesting fact, the flowers are not pollinated by moths, butterflies or bees, which is different to almost all flowers in the world. The flowers of a cocoa tree are in fact pollinated by *Forcipomyia* midges, a kind of tiny flies recognized in the subfamily *Forcipomyiinae* (Hernández, 1965). Every cocoa tree produces a fruit called a cocoa pod, which grows from a pollinated flower. One pod has a white pulp that embeds about 20-60 beans as the seeds of future cocoa trees (Figueira *et al.*, 1993; Coe and Coe, 1996). In terms of geometrical dimensions, a full-grown cocoa tree is generally measured in between 4-8 m tall, with leaves sized approximately 10-40 cm long and 5-20 cm wide in a fully flatten state. Every cocoa flower has a pink calyx, and sized only 1-2 cm in diameter. Then, a cocoa pod is more or less egg-shaped, which is also called as ovoid, and sized approximately 15-30 cm in length and 8-10 cm in width. In general, a ripening pod has a yellow-toorange color, and weighs approximately 500 g (Coe and Coe, 1996; Glendinning, 1963).

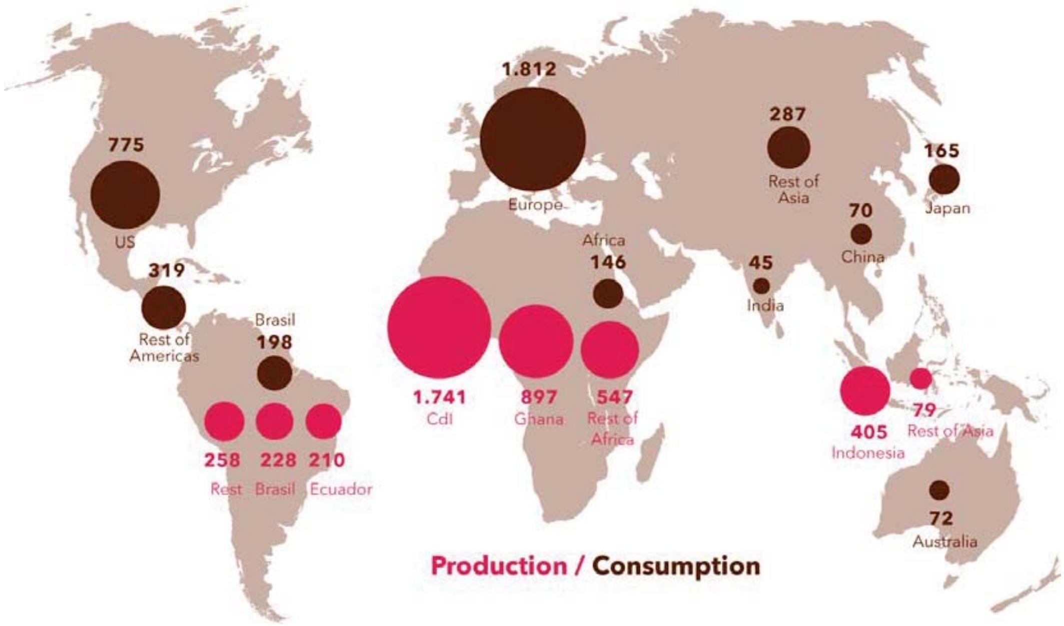


Figure III.1. World cocoa production and consumption in 2014.

Historically, cocoa tree is natively recognized by indigenous Americas (Hurst *et al.*, 2002; Coe and Coe, 1996). In particular, it is originated from Amazon rainforest (South America) and Central America as well as some regions in Mexico (North America). In fact, the rainforest is acknowledged as the biggest tropical forests in the world, and has been taking a critical position within the society and a large portion of surrounding cultural development for more than 2000 years. In general, the arrival of European colonization to those regions noted the spreading of cocoa beans to all around the world as a primary traded agricultural commodity for foods and beverages alongside coffee beans (Leiter and Harding, 2004). Before the arrival of those Europeans, Mayan and Aztec have been found to be the first indigenous tribes in the ancient world who applied cacao as a main ingredient for some of their foods and drinks (Hurst *et al.*, 2002). These two Mesoamerican Indians are also stated as the first communities who created drinks from cocoa powder mixed with water, which was then given vanilla, pepper or other flavors. It was originally posited as a special drink devoted to Mayan leaderships or for being used during spiritual ceremonies. In fact, the literal meaning of the Latin name of cocoa (*Theobroma*) is a “food of the gods” (Dillinger *et al.*, 2000; Hurst *et al.*, 2002). Besides, Mayans have ever applied cocoa beans as their formal trading currency. For example, a Spanish legend has been telling a story about a rabbit that was exchanged at 10 cocoa beans price during the 16th century, while a small donkey was priced at 50 cocoa beans at the time. In the history, Spanish learned things related to cocoa from Aztec people during the 15th century (Snodgrass, 2003; Dhoet, 2010; Moreno, 2011). In Spain at the time, cocoa was treated as a treasured drink, which was only served for the king. They usually served it with the addition of sugar and honey, and drank a cocoa drink while it was still hot. Later, cocoa gradually spread throughout European continent during the 17th century by being treated as a special gift between noble families.

In the contemporary world, cocoa has gained a position as a special constituent in the dietary of men. It has assumed an importance as an agricultural commodity being traded with a huge influence to the society (Wickizer, 1951; Sianipar and Widaretna, 2012; Coe and Coe, 1996; Dillinger *et al.*, 2000; Hurst *et al.*, 2002). In fact, it has been recognized as one of the world’s most important perennial crops. Today, cocoa is widely consumed throughout American and European continents, while it is also consumed in a lesser volume to some extent in the rest of the world regions (Figure III.1). On consumers’ side, the United States, Germany, France, the United Kingdom and Russia are the largest cocoa consuming countries, respectively (World Cocoa Foundation, 2014). As an interesting fact, the global demand shows a consistent 3% annual increase since 2008. The steady increase is argued to occur due to the increase of household income in many developing countries, while those in Europe and North America continents perform relatively stable cocoa markets. On producers’ side, small cocoa plantations practically exist in almost every tropical region in the world; however, commercial plantations in larger sizes are established and operated in some particular countries within the tropical latitudes (Figure III.1). With no particular order, some major ones include the Ivory Coast, Ghana, Indonesia, Brazil, Malaysia and Mexico (ICCO, 2012). During 1974-2013 (39 years), world cocoa production increased 194.6%, indicating a 2.81% of compound annual growth rate. In between consuming and producing countries, some countries have been taking a role as processing regions, transforming cocoa powder to different product derivations for being further traded in international market (World Cocoa Foundation, 2014; ICCO, 2012). While the market share for processing has been remaining stable globally despite having a consistent increase in terms of the total grinding volume to meet demand, Europe and Russia, which are two regions outside tropical latitudes, have been constantly covering a large portion (38%) of the market share. Among Europeans countries, the Netherland handles around 13% of the world's total grinding volumes.

III.1.2 Cocoa in Indonesia: Aceh as a sample case

In Indonesia, cocoa tree was brought circa five centuries ago to a region named Nusantara at the time. The existence of cocoa trees in the country was in fact tightly related to the arrival of Europeans to Nusantara archipelago (CoMC, 2007; Ruf and Ehret, 1996; Murray-Li, 2002; Ruf and Schroth, 2004). In particular, some important events include the arrivals of Portuguese sailors under the leadership of Bartholomeus Diaz in 1492, and a sea expedition led by Vasco da Gama in 1512 after a short visit to Calcutta, India, in 1511. Approximately five decades later, Spanish sailors introduced cocoa trees to Minahasa (North Sulawesi) in 1560. The plant variant being introduced was *Criollo Venezuela*, which was taken from the Philippines. In fact, it was the first cocoa plant variant entered the Nusantara, and cultivated until the 18th century. In 1880, another variant (*Forestaro*) from Venezuela was introduced to the archipelago, while the same *Criollo* was introduced again in 1888 and later recognized as *Java Criollo*. The advantages of having *Forestaro* include a high yield and a strong resistance to diseases and pests, despite having a bitter taste. On the other hand, the *Java Criollo* had further clone derivations, including *Trinitario Djati Roenggo*. It was the ancestor of recent DR (*Djati Roenggo*) variants, which marked the beginning of the existence of cocoa-related researches in Indonesia.

Early cocoa plantations in Indonesia is historically noted to establish in Minahasa, North Sulawesi, in 1820. It is supported by the fact in which the first export of cocoa beans was taken in 1825 from Manado port, North Sulawesi, to the Philippines. Until 1838, exported volumes through the port increased to achieve 92 tons. The growth also boosted cocoa as a very valuable trading commudity around the 19th century, as indicated by its high and considerably stable inflation-adjusted price at the time compared to other periods in the history (Figure III.2). However, the growth did not last long due to consistent decreases of the export to 30 tons in 1909 until it finally achieved a zero export in 1930. In fact, the growth of cocoa plantations in Indonesia was originally driven by those in Java island. The development of cocoa plantations in the island began in 1880 when there was a widespread fungal attack (*Hemileia vastatrix*) to existing Arabica coffee plants. During the event, coffee farmers began to consider planting cocoa trees as an alternative plant. In 1930, a large portion of cocoa plantations in Indonesia existed in Java island. The difference in terms of export volume was so huge, showing 1.408 tons from Java and only 55 tons from other regions in the archipelago. At the time, a considerably large plantation outside Java island was only in Payakumbuh, West Sumatra. Circa 1980s, there was a rapid growth of cocoa plantations in Indonesia, which was particularly directed to regions outside Java island. Those regions include Sumatra, Kalimantan, South Sulawesi, Southeast Sulawesi, West Nusa Tenggara, East Nusa Tenggara, Maluku and Irian Jaya (Papua/West Papua). In the current market situation in the world, Indonesia has gained the third biggest cocoa producer in the world after Ivory Coast and Ghana. In general, cocoa plantations in Indonesia cover no less than 1.2 million hectares, with an annual production of 600.000-700.000 tons.

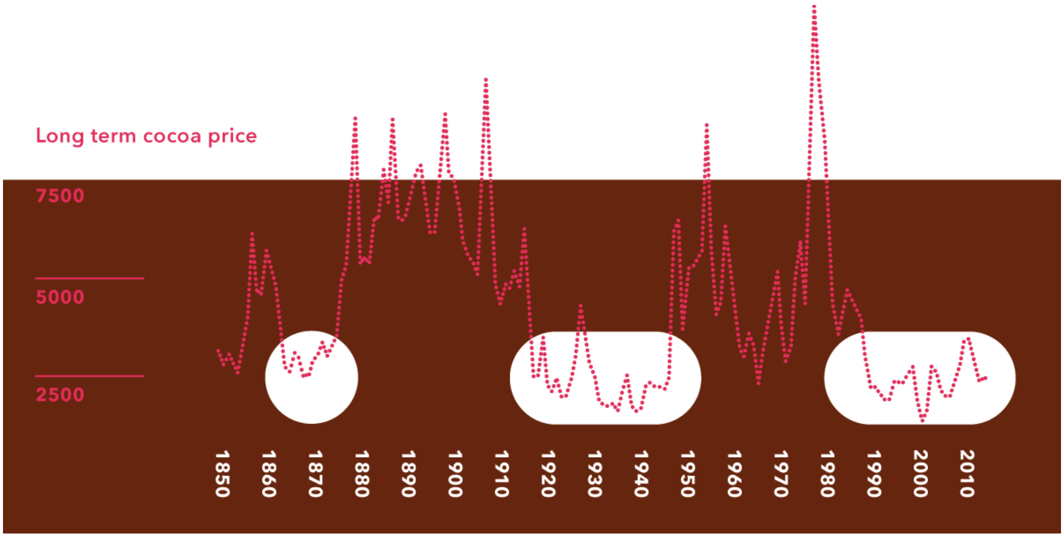


Figure III.2. Long term inflation-adjusted cocoa price.

In Indonesia, cocoa is traditionally the third most exported agricultural commodity after CPO and rubber, the two which always led the Indonesian agricultural export figures, and it is contributing export earnings in excess of US$1.4 billion per year. Particularly, cocoa cultivation in Indonesia depends much on the private plantations by small farmers, with the percentage almost 93% of total cocoa cultivation area throughout Indonesia by which small farmers contribute around 90.5% of Indonesia national cocoa production. In a real number, cocoa plantations in Indonesia have been involving more than 1.4 million farmers and their families/communities. Looking at those figures, the production rates of Indonesian small farmers are far below other cocoa producers, *i.e.* government-owned plantations or heavy-investment plantations by big private firms. Although small farmers have a huge amount of cocoa cultivation area, they contribute less than the portion of their plantation area to the total national cocoa cultivation area. In short, the huge portion of cocoa plantation owned by small farmers and their low production rate have indicated that such kind of plantation system is very critical to the Indonesia's national cocoa production performance. Besides, smallholder farmers in Indonesia only gain about 6.6% of value chain distributed throughout cocoa value chain the are involved (Figure III.3). It is generally below other supply chain members, and even similar to traders who practically do not practicing a complex work as what farmers do in their on-farm and postharvest processing activities. Hence, there is an urgent need to conduct significant improvements from any possible approach.

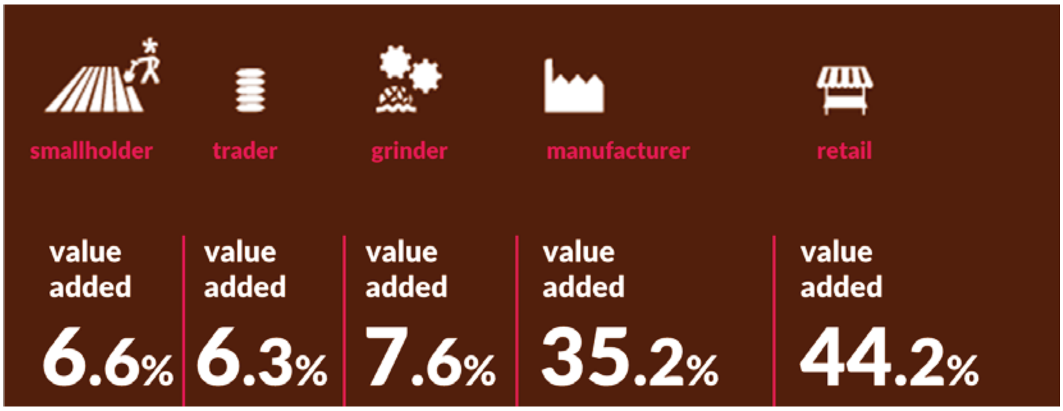


Figure III.3. General cocoa value chain in Indonesia.

At its national level, the improvement on Indonesia cacao production had been started since 2008 with a program named *Gernas Pro Kakao* (*Gerakan Nasional Produksi Kakao*/National Movement for Cacao Production) conducted directly by the government of Indonesia. The program was initiated to revitalize cocoa industry, with a particular focus on replacing ageing trees to get an increase in yields as well as planted area, allowing Indonesia to compete with Ghana, the world's second largest producer. The targeted view of the program was around 55% cocoa production growth to 2014/15. However, the facts say otherwise. When the *Gernas Pro Kakao* program was started, the Indonesia national production reached 803.6 x 103 metrics ton, yet in the fifth year (2012), the production level reached only 833.3 x 103 metric ton, or about 3.695% production growth. It was almost the same compared to the 3.7% year-on-year growth with an exclusion of 2011's significant decline (-15%) argued as a statistical anomaly. In short, after around 60-70% timeline progress the *Gernas Pro Kakao* program has never achieved a significant result even though it had ever produced a promising 8.59% growth in the beginning of its initiation. Looking at those abovementioned facts, the revitalization of cocoa industry at national level have indicated two significant yet counterproductive factors: (1) huge portion of cocoa plantation owned by small farmers with the low production rates; and (2) incapability of national government to increase the on-farm production quality. These two factors have revealed the gap between the real condition on fields and the governmental effort at national level. There might be something missing in increasing the production capacity of small farmers as the biggest contributor of cocoa industry.

To understand the problems, the focus of investigation needs to be pushed down into a lower level: regional area. The characteristics of Indonesia as an archipelago has made the spread of any industry into separated islands, including cocoa industry. It creates significant disparities in accessing required resources to improve cocoa industry as a whole, including production rates as its critical measurement. Furthermore, Indonesia has undergone a critical transformation since circa a decade ago, in which there are significant authoritative delegations from national government to regional ones particularly to municipal governments, including decision making for activities on fields. Besides, municipals, as the direct policy makers for small farmers, have the higher impacts to the industry by regulating the operational systems of cocoa industry at its smallest level between farmers and direct buyers. Also, municipal is the nearest authoritative government whom small farmers have access to, meaning that the partnership between small farmers and municipal government is very critical to the improvement of cocoa industry. Therefore, the investigation on cocoa industry would have direct benefits to the industry when it is conducted over municipals.

Among cocoa production area in Indonesia, Aceh and Nias have the most vulnerabilities to either economic crisis, environmental hazard, or social conflicts. Those areas exist in the most Western part of Indonesia, far from Java as the center of Indonesia national economic growth. In addition, those areas experienced the world's heaviest tsunami ever recorded in 2004. Among those two, Aceh (Figure III.4) is widely recognized as the more unstable and hence a very vulnerable area due to several reasons, including prolonged social conflicts, environmental vulnerabilities, *e.g.* tsunami as well as earthquake, and slow economic growth despite its agriculture potentials. Besides, there is a lack of access to technological solutions for improving cocoa industry in Aceh. In short, conducting a research for developing technological solution for vulnerability eradication in Aceh is necessary, and Aceh is the perfect case to show an example of improving cocoa industry in Indonesia by conducting a holistic and systemic problem solving over the country's most vulnerable cocoa-producing region.

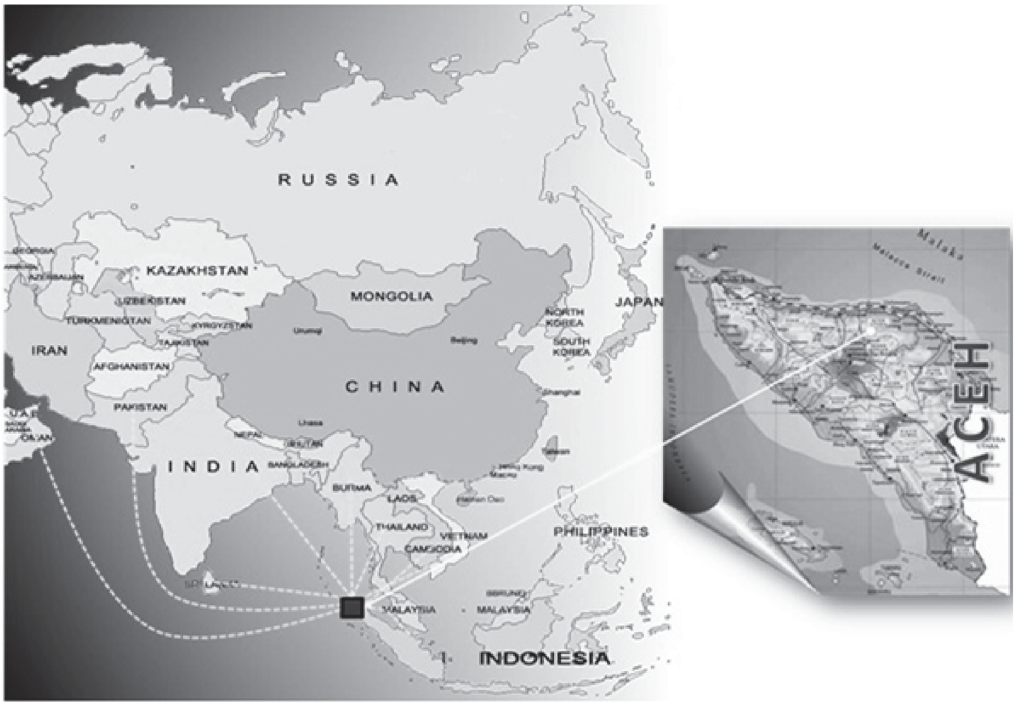


Figure III.4. Position of Aceh.

III.2 Problem solving approach

III.2.1 Postharvest engineering and Appropriate Technology

Developing countries have been known as being dependent to agricultural commodities either as trade items or for domestic consumptions (Reardon and

Timmer, 2007; Sianipar *et al.*, 2014b). Hence, having an effective and efficient supply-chain is critical for those countries (McCullough *et al.*, 2008). However, developing countries have long been dealing with complications in their agricultural supply-chains (Haggblade *et al.*, 2007; McCullough *et al.*, 2008). In general, those countries do not have a sufficient capability to maintain the stability of their production, making them to get reliant to seasonal supply and demands. Besides, their inefficient supply-chain activities have been known to produce high emissions, raising the emission factor of the whole chain. In fact, there is also a concern on inequality between supply-chain members, in which there is a strong economic disparity between upstream and downstream parties, making farmers to have the least economic benefits for their own productions. As a result, social conflicts of interests are unavoidable, causing disrupts to ongoing activities within a supply-chain. In fact, these complications affect each other, resulting in a cyclical deterioration of the whole chain. Thus, agricultural supply-chain in developing countries require a fundamental transformation to solve its latent problems (Dorward *et al.*, 2004; Reardon and Timmer, 2007). Furthermore, any action to pursue the transformation needs to consider existing situations and social capitals, in which all actions are dedicatedly taken to strengthen indigenous capabilities (Rodenburg *et al.*, 2014). In other words, less interventions are preferable, ensuring the sustainability of a transformation.

In many developing countries, a widely preferable solution to apply is capacity building for people. It is particularly targeted to local producers as a means to increase their capability in improving work efficiency (Eade, 1997; Honadle, 1981; Pretty, 1995; Simoes *et al.*, 2010). By building their capacity, the resulted higher work efficiency is then posited as a way to improve either quality or quantity of a supply chain in which they are involved, and then their agricultural product. Besides, the built capacity may influence their capability in applying other additional or artificial solution, including the use of new technology or the implementation of new agricultural system. In a general sense, capacity building has been recognized as being able to improve the current performance of an agricultural supply chain by enhancing its immediate actors (people) and providing a way to further improve the supply chain by opening more potentials to introduce better artificial solutions in a staged process over time. However, the application of capacity building to people involved in a targeted agricultural supply chain may also impose unintended consequences. First, capacity building requires people to learn things, in which any learning process requires time, which then opens a potential of a lengthened learning curve to achieve a targeted capacity level. During steps at the learning curve, local people are in a transitional period, which also produces a transitional period for their plantations. The transition usually requires a change in their behavior in conducting agricultural activities, and affecting the yield to have a more unstable result compared to their business-as-usual. In other words, capacity building may be stated as a good solution for a group of local people with a considerably good learning curve, meaning that they consume a shorter period to learn knwoledge they need to gain compared to those with a weaker learning curve. For the latter type of group, capacity building does not offer any immediate benefit as they require a lengthened time to perform well as they are required by any capacity building process they are involved with.

Among known non-people-targeted solutions, on the other hand, some suggested ideas include irrigation (Qadir & Oster, 2004; Watson *et al.*, 1998), the improvement of cultivation methods (Morris, 2007; Tilman *et al.*, 2002), and postharvest engineering (PhE). Irrigation and improved cultivation methods are known as on-farm strategies, while PhE is posited as an ex-farm one. On-farm strategies have been recognized as having heavy interventions to any current plantation, *e.g.* a provision of reduced planted land due to the construction of irrigation. The provision of infrastructure as such may consume a lengthened time and energy, let alone numerous potentials for the occurrence of either horizontal conflicts between pro and counter opinions among local people or vertical conflicts between local people and a provider of the infrastructure (the government or private sector). Besides, improved cultivation methods may also deliver a huge intervention to ongoing plantations. For example, an engineered seed that is stated as having a better yield when it grows to a ready-to-harvest plant imposes a need to replace the whole plantation as a means to ensure the full impact of the improved seed. It hence requires farmers to put a huge investment for the replacement seeds, including more in the process of getting rid of replaced plants. On the other hand, farmers with less funds may delay the replacement by waiting current plants to getting older and unproductive; however, the choice lengthens the effect of the improved seeds, and produces insignificant benefits for farmers for a number of uncertain periods. Another example, the use of new fertilizer, may arise as an improvement of current cultivation method. It usually suggests an improved performance of the new fertilizer compared to the old ones, making it potential to support a better yield or a reduced effect from pests. However, it also imposes new problematic situation in which new fertilizer may trigger the mutation of current pests, making them more immune to more number of artificial treatment. Besides, any fertilizer is known as having negative effects to human health, which is not suggested to produce an organic and healthy agricultural product.

Turning on a limelight over these arguments, PhE arises as an approach offering less interventions to the whole parts of a chain, yet potential to bring significant effects throughout the chain. As an ex-farm strategy, PhE targets a critical connection between farmers as the least benefitting societal group within a chain in a downstream direction (Hodges *et al.*, 2011; McCullough *et al.*, 2008), which may then improve their bargaining position in the whole chain. However, it may also bring significant changes to some particular spots in a chain, which, as aforementioned, may get risky due to complications in agricultural supply-chains in less developing countries (Kitinoja *et al.*, 2011; Haggblade *et al.*, 2007; Hodges *et al.*, 2011). Thus, conducting PhE requires a parallel approach to put more emphasis on local capabilities while delivering least interventions. In that spirit, appropriate technology (AT) may complement PhE by offering a robust focus on local capabilities and existing situation as its basis of development. As an install-and-done solution, it has been recognized as an effective technological solution for any given situation that originally has least sustainable prospects (Kaplinsky, 2011; Sianipar *et al.*, 2013c). Conducting PhE and AT in parallel, therefore, has a great potential to deliver a significant transformation into an agricultural supply-chain with as small as possible intervention, while also strengthening existing local values to sustain the transformation in any further supply-chain development. Furthermore, an AT is a result of four different views, *i.e.* technical, economic, environment and social (Sianipar *et al.*, 2013c). Thus, conducting PhE and AT may then trigger four different transformations in a supply-chain following these views. While each view has its own focuses, these views may affect each other in producing an AT, hence boosting PhE to comprehensively transform the chain.

III.3 Theoretical influences

An agricultural supply-chain is a system of networked interactions between the supply and demand of an agricultural commodity, involving producers, *i.e.* farmers, and buyers, *e.g.* middle-men/intermediaries to end users (McCullough *et al.*, 2008). Practically, it includes people, institutions, activities, and resources to move the commodity. In particular, PhE may cover any ex-farm activity, including temperature management, storage, transportation handling, sorting or grading and packaging of a commodity. In fact, any agricultural commodity is a biological material, which gets transformed by nature over time (Holzapfel, 2002; Yindee, 2014). Thus, postharvest actions are supposed to maintain its quality and deliver a high-quality product throughout all supply-chain phases (Kitinoja *et al.*, 2011). From its position, an AT may support the purpose by spreading staged enhancements (Figure III.5). At first, applying an AT to support a PhE action in a supply-chain means adding another network of local activities, including all stages of its lifecycle from construction to disposal (Sianipar *et al.*, 2014b). Second, an AT enhances the internal process of an activity to which it is purposely designed (Sianipar *et al.*, 2013c). Third, an AT transforms the effectivity of resources to transform inputs to outputs of the process, hence improving its efficiency (Hodges *et al.*, 2011; Rodenburg *et al.*, 2014). Fourth, an AT affects downstream processes, moving some activities to earlier supply-chain stages due to improved capabilities of the earlier processes (Haggblade *et al.*, 2007; Kitinoja *et al.*, 2011; Park and Ohm, 2015; Sianipar *et al.*, 2013b). Then, the AT pushes benefits towards an upstream direction due to more values added to those earlier activities.

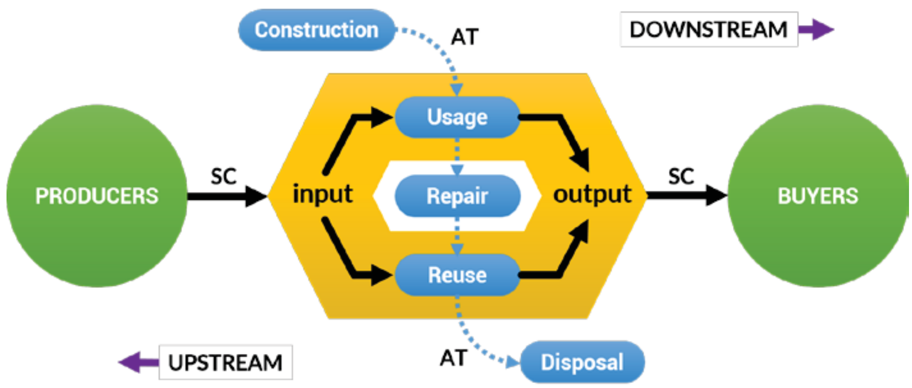


Figure III.5. Theoretical influences.

III.3.1 Expected technical transformations

Basically, AT offers a technically-functioning solution based on indigenous knowledge of locals. Practically, it performs a specific postharvest activity, e.g. fermentation, drying, *etc*. In fact, AT is purposely designed to enhance PhE as a means for delivering a better postharvest activity without significantly changing the activity. Within the activity, AT performs a faster process compared to any conventional approach. Besides, it uses less forces to do similar sets of sub-processes within the activity. Then, an AT produces a better result in comparison to the original activity. Furthermore, conducting PhE using an AT uses less technical resources due to its properly-designated design, which is appropriately fitted to a targeted activity. In other words, it maximizes resources utilization for the activity. In a downstream direction, an enhanced process within an earlier postharvest activity may reduce additional processing that originally arises to compensate the lower results of earlier supply-chain phases. On the other hand, it triggers improvements on the technical capabilities for upstream activities as the results of more technology-enhanced processes (Table III.1).

Table III.1. Expected technical transformations

Affected	Supply-chain network	Appropriate technology network
Internal process	a. Faster process (time dimension) b. Less forces (ergonomic dimension) c. Better result (performance dimension)	a. Less technical dependencies b. Durable usages (time and performance dimensions)
Input & output		
● Effectivity	Uses less technical resources, *e.g.* materials, tool, *etc*.	a. Reduces foreign inflows of resources b. Increases technological accessibility
● Efficiency	Maximized resources utilization	a. Spin-off existing local technology-related processes b. Establish an autonomous technological solution
Downstream	Reduced additional downstream processing	Triggers local repair- and disposal-related activities
Upstream	Adds more technical capabilities to upstream processes	Triggers local construction-related activities

In terms of additional network due to the use of AT, an appropriately-designed solution produces less technical dependencies to the outside region, resulting in a more autonomous technical development. Besides, the AT offers a better durability compared to conventional solutions. The durability may indicate the longer usage period of a technological solution, or a higher capacity of the technology to process more inputs to produce multiplied outputs. Furthermore, a lower dependency also triggers a reduced inflow of resources, hence reducing the outflow of capitals. In fact, an AT produces a better technological accessibility due to the more opportunities of local people to develop their own technological solutions, improving its scalability. By seamlessly integrating the solution to its designated activity, existing local technology-related processes are spin-off, making people able to have a higher productivity while conducting a similar set of processes. In a downstream direction, an AT-enhanced PhE triggers local activities related to the repairs and disposal of the AT. In particular, repairs are critical to lengthen the use of an AT while maintaining its performance. Then, in an upstream direction an AT also triggers construction-related activities to increase its scale.

Table III.2. Expected economic transformations

Affected	Supply-chain network	Appropriate technology network
Internal process	Better product prices (price dimension)	Affordable expenditure (cost dimension)
Input & output ● Effectivity ● Efficiency	 Less costs for same margins More added values at same expenses	 Extended period of investments Short returns (profit dimension)
Downstream	a. Reduced expenses for similar margins b. Redistributed economic benefits	Increases economic values for local repair and disposal works
Upstream	a. Adds more financial values b. Redistribute economic benefits c. Improves economic bargains	a. Triggers more economic activities for local construction works b. Increases more local transactions on materials and tools/equipment

III.3.2 Expected economic transformations

In parallel to technical transformations of a system, economic disadvantages may arise as the results on the increasing investment for a technological solution. However, AT delivers more economic advantages for a PhE process being improved, and hence refining economic benefits for involved phases and parties (Table III.2). Within a process being improved, there is a transformed price of commodity being treated. An AT basically improves the performance of the process, and thus producing a better product. A better quality may then set the price at a higher level. Related to processed input and output, less costs are required for same margins. In other words, treating the same amount of inputs to produce the same outputs for a desired price requires lower expenses. In parallel, spending the same amount of expenses would produce more added values due to the enhanced process. In a downstream direction, higher level buyers get reduced expenses due to less additional processes for the commodity. Then, economic benefits would be redistributed to the upstream direction, by which lesser levels of supply chain members get more financial values and higher economic bargains.

On the other hand, AT connects another economic network to the supply-chain, which is attached to the economic benefits of the process being intervened. Basically, using an AT to conduct PhE offers affordable expenditure compared to a more advanced technology with an excessive number of functions, delivering lower investments for a technologically-enhanced process. Besides, the investments involve a longer period of usage compared to those of a conventional process, producing a better deal for the same period of time. Furthermore, an improved performance produces better product price, accumulating more returns in a normal investment period compared to a conventional process. In other words, returning the same investment for a technological solution requires a shorter time. In either downstream and upstream directions, an AT triggers more activities with economic values. In a downstream direction, those who are able to do repairs and disposal on an AT being utilized may gain more economic benefits. Besides, some other economic values are gained by construction workers, while there are also increased local transactions on materials/equipment.

III.3.3 Expected environmental transformations

As an environmentally-appropriate technology, an AT enhances a targeted PhE activity with less emitted emissions compared to other methods that offer more technical functions. Having fitted functions with a better performance, the AT-enhanced PhE activity may produce a less amount of emissions per mass produced outputs. Thus, it decreases the emission factors of the whole activity being intervened. In a downstream direction, the improvement of an earlier supply chain phase reduces the needs of emissions-imposing activities in later phases that may originally appear to raise the quality of low-qualified outputs from early phases with no AT-enhanced PhE activity. In fact, there is a less number of downstream actors than in the upstream direction. Removing the needs of additional processing from later phases, therefore, also reduces geographical concentration of emitted emissions. In an upstream direction, using an environmentally-appropriate technology produces more organic wastes at a low emission, feeding more natural residues to the environment. Besides, more eco-friendly works in early supply chain phases improves the cycles of nature at nearer positions to farms, ensuring the creation of nutrition surrounding the production regions of an agricultural commodity.

The AT network, in parallel, introduces less environmentally-destructive mechanisms to existing local processes. Despite having been conventional, previous processes may have promoted simple efforts at the cost of nature exploitation. An AT promotes otherwise, hence preventing any further exploitation to the nature. Besides, an AT performs in a lengthened lifecycle to ensure that people use all of its potentials in conducting a PhE process. Any AT-related activity also puts an emphasis on producing less wastes due to its fitted design for the particular PhE. In a downstream direction, repairing and disposing an AT do not disrupt the environment because the maintained materials degradability and disposal process, which are purposely designated since its development. Then, upstream direction promotes the lesser usage of emissions-emitting construction processes and the reduced uses of materials and equipment with non-environmentally-friendly characteristics (Table III.3).

Table III.3. Expected environmental transformations

Affected	Supply-chain network	Appropriate technology network
Internal process	Reduced emissions	Less environmentally-destructive mechanisms
Input & output ● Effectivity ● Efficiency	 Less emissions per mass product Reduced emission factors	 Lengthened lifecycle Less wastes
Downstream	a. Reduced emissions-imposing activities from later additional processing b. Reduced geographical concentration of emitted emissions	a. Maintain materials degradability b. Maintain environmentally-friendly disposal processes
Upstream	a. Feeds organic wastes and low emissions to the environment b. Improves cycles of the nature at nearer positions to farms	a. Less emissions-emitting construction processes b. Reduced non-environmentally-friendly materials

III.3.4 Expected social transformations

In addition to technical, economic, and environmental effects, doing PhE using AT offers social transformations. In fact, social-related benefits are the most critical and desired effects in transforming an agricultural supply-chain in a developing country. Thus, transformations on social-related issues must be properly investigated. First, existing social processes in an activity being intervened are transformed. Using an AT produces more interactions between local people due to the strong involvement of locals in all AT-related PhE actions. It occurs not only in terms of quantity but also quality, because locals are being treated as equal according to their indigenous capability, and hence making an improved social mapping between them. Furthermore, the treatments spread responsibilities to proper people to ensure the process and results, triggering more understanding between locals on different capabilities that may complement each other. As an additional result, it produces less conflicts of interests due to properly-divided responsibilities and loads in taking part in an AT-enhanced PhE action. In a downstream direction, it produces less uncertainties of trade partnerships due to the certain involvement of locals with more certain responsibilities and less conflicts in their works at an early upstream activity. Thus, locals get higher social bargains due to a tighten relationship between themselves and between them and their trade partners.

Table III.4. Expected social transformations

Affected	Supply-chain network	Appropriate technology network
Internal process	a. More interactions between locals b. Improved social mapping	More local workers
Input & output		
● Effectivity	Properly-spread responsibilities	Uses existing local knowledge
● Efficiency	Less conflicts of interests	Less resistances
Downstream	Less uncertainties of trade partnerships	Improves local repair- and disposal-related knowledge
Upstream	a. Increases social bargains b. Less uncertainties of local works	a. Improves construction knowledge b. Triggers local educations

On the other hand, social transformations are also triggered by the AT network from its construction to usage, repair, reuse and disposal. Adding an additional network intersected to an agricultural supply-chain right at a PhE activity being enhanced requires more workers, thus increasing job opportunities for locals. Furthermore, using an AT to enhance a PhE action strongly suggests the use of local knowledge in terms of technical, economic, environmental and social understandings, which may then extend to include cultural, judicial and political subjects. These existing knowledge produces a more effective PhE action due to a lower need for capturing knowledge from outside regions. Besides, a particular emphasis on existing local knowledge triggers less resistance of locals to either a PhE intervention or a new technology. In down- and upstream directions, it also improves existing knowledge to treat an AT during its lifecycle. Then, utilizing existing knowledge to conduct an AT-enhanced PhE activity may encourage local educations to promote more enriched knowledge due to sustained shifts of developmental purposes in the future (Table III.4).

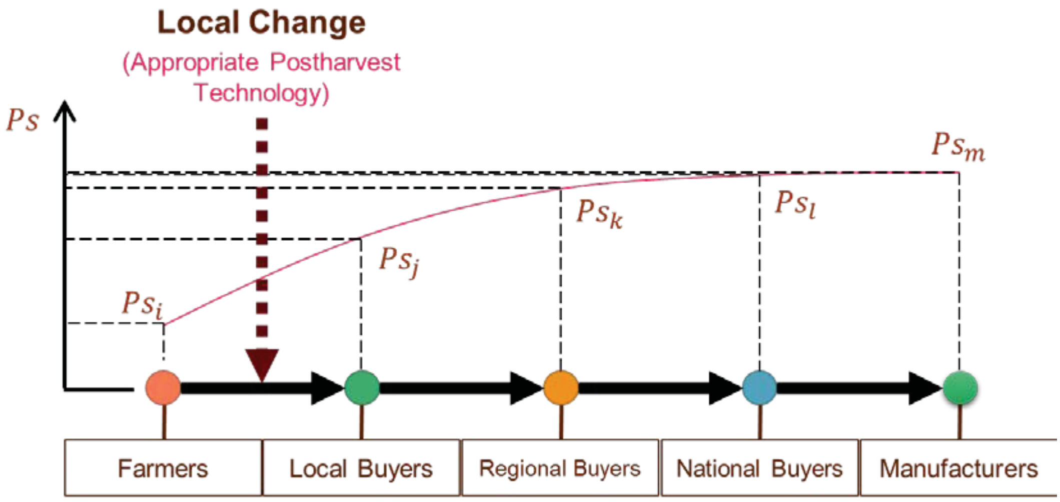


Figure III.6. Intervention to push a new system.

III.4 Theoretical systemic expectations

An agricultural supply-chain is a system of networked interactions between the supply and demand of an agricultural commodity, involving producers, i.e. farmers, and buyers, e.g. middle-men to end users (McCullough *et al.*, 2008). Practically, it includes people, institutions, activities, and resources to move the commodity. In particular, PhE may cover any ex-farm activity, including temperature management, storage, transportation handling, sorting or grading and packaging of a commodity. In fact, any agricultural commodity is a biological material, which gets transformed by nature over time (Holzapfel, 2002; Yindee, 2014). Thus, postharvest actions are supposed to maintain its quality and deliver a high-quality product throughout all supply-chain phases (Kitinoja *et al.*, 2011). From its position, an AT may support the purpose by spreading staged enhancements (Figure III.1). At first, applying an AT to support a PhE action in a supply-chain means adding another network of local activities, including all stages of its lifecycle from construction to disposal (Sianipar *et al.*, 2014b). Second, an AT enhances the internal process of an activity to which it is purposely designed (Sianipar *et al.*, 2013c). Third, an AT transforms the effectivity of resources to transform inputs to outputs of the process, hence improving its efficiency (Hodges *et al.*, 2011; Rodenburg *et al.*, 2014). Fourth, an AT affects downstream processes, moving some activities to earlier supply-chain stages due to improved capabilities of the earlier processes (Haggblade *et al.*, 2007; Kitinoja *et al.*, 2011; Park and Ohm, 2015; Sianipar *et al.*, 2013b). Then, the AT pushes benefits towards an upstream direction due to more values added to those earlier activities.

Looking at the explanation of conducting a combination of postharvest engineering and appropriate technology in a supply chain, system under investigation is stated as a networked complex system. In terms of the supply chain, there will be networked chains, meaning that there is an interconnected supply chain involving different supply paths. Hence, it is possible to have different stages of supply at an interconnection, making the whole networked supplies as a complex system. To understand the whole system, it is better to at first simplify it into a single supply flow (Figure III.6). In general, three types of members are involved within a supply path, *i.e.* producers (farmers), intermediaries and manufacturers. A supply activity flows from producers to buyers (intermediaries) to manufacturers. Because in the current situation farmers cannot do proper postharvest activities (fermentation and drying), there is a critical need to do additional processing by latter supply chain members. Figure III.6 shows an example of the need. If Ps is the need of additional processing, and $i \ldots m$ are supply chain stages/members, the need for postharvest processing rises as commodity being processed (cocoa) flows to latter members. In general, additional processing occurs at large at the immediate stage after producers ($Ps_j - Ps_i$) due to the immediate need of doing postharvest engineering, which is not practical for farmers without having a (appropriate) processing technology in the current situation. In a common situation, investments for improving the supply chain will be focused on advanced technologies and/or heavy changes throughout the system. However, those efforts are less preferable in the current research due to the vulnerability of cocoa industry in Aceh to any shocking change and/or significantly artificial intervention. Thus, appropriate technology being introduced is given as a local change between producers (farmers) and first level buyers (immediate intermediaries).

Basically, the local change is intended to avoid shocking change to the whole industry, while pursing direct impacts to the least developing supply chain members (farmers). Thus, the appropriate postharvest technology being introduced requires further analyses to also investigate its influences to downstream direction, revealing its bigger impacts to the whole cocoa industry through its interconnected supply chain flows. Besides, the local change is particularly intended to simplify an excessively long supply chain by reducing the need of having too many intermediaries in between producers and manufacturers. The need is reduced by moving postharvest processing activities to farmers. After the reduced need of intermediaries, farmers will have more bargaining power to sell their products to any immediate buyer, while also opening opportunities for them to cut one or more supply chain stages by selling their products directly to higher level of buyers. Thus, the supply chain system will simplify itself due to the simplified trading stages, including technical, economic and environmental attributes attached to the trades. In other words, introducing one appropriate postharvest technology to every farmer as a local change can be expected to affect the whole supply chain. The effect will be larger after farmers have enough savings to expand the processing capacity of the first-given appropriate postharvest technology by replicating it by themselves.

Chapter IV CASE STUDY
Supply-chain system under investigation

IV.1 The current state of cocoa industry in Aceh, Indonesia

IV.1.1 Characteristics based on production and plantation area

As theh first step to investigate potential improvements in the cocoa industry over municipals in Aceh, there is a need to explore the current condition of the industry in the region. Besides, data on existing condition of cocoa industry in Aceh's municipals, which act as nodes in the supply chain being observed, are required to understand the starting point of further investigation. However, existing data are limited at national and regional level due to the prolonged social conflicts in Aceh. There is also a known incapability of regional government to gather data in their own area due to social frictions. In other words, conducting research in Aceh's municipals require direct observation on fields, including data gathering from small farmers participated in cocoa industry. Thus, improving cocoa industry over Aceh's municipals requires an on-site research.

In this research, Appropriate Technology, which is constructed as an artefact and stated as being given in the beginning of introduction, is integrated into a supply-chain system of regional cocoa industry in Aceh, Indonesia. The introduction of a technical artefact into a system indicates potential to build a system modeling of dynamic assessment on the supply-chain by proposing some possible scenarios on the application of the appropriate technology being introduced and supply/value chain settings. Despite its focus on Aceh as a whole, this research requires a couple of particular focuses, covering one of the best and one of the worsts municipals offering cacao as their trade commodity. These particular focuses are purposed to reduce an extensive and repeated reviews on municipals with similar characteristics. In other words, these focuses are useful to simplify the whole analysis, yet maintaining its coverage on different sets of field situations. To do so, an investigation on the current state of cocoa industry in Aceh is required.

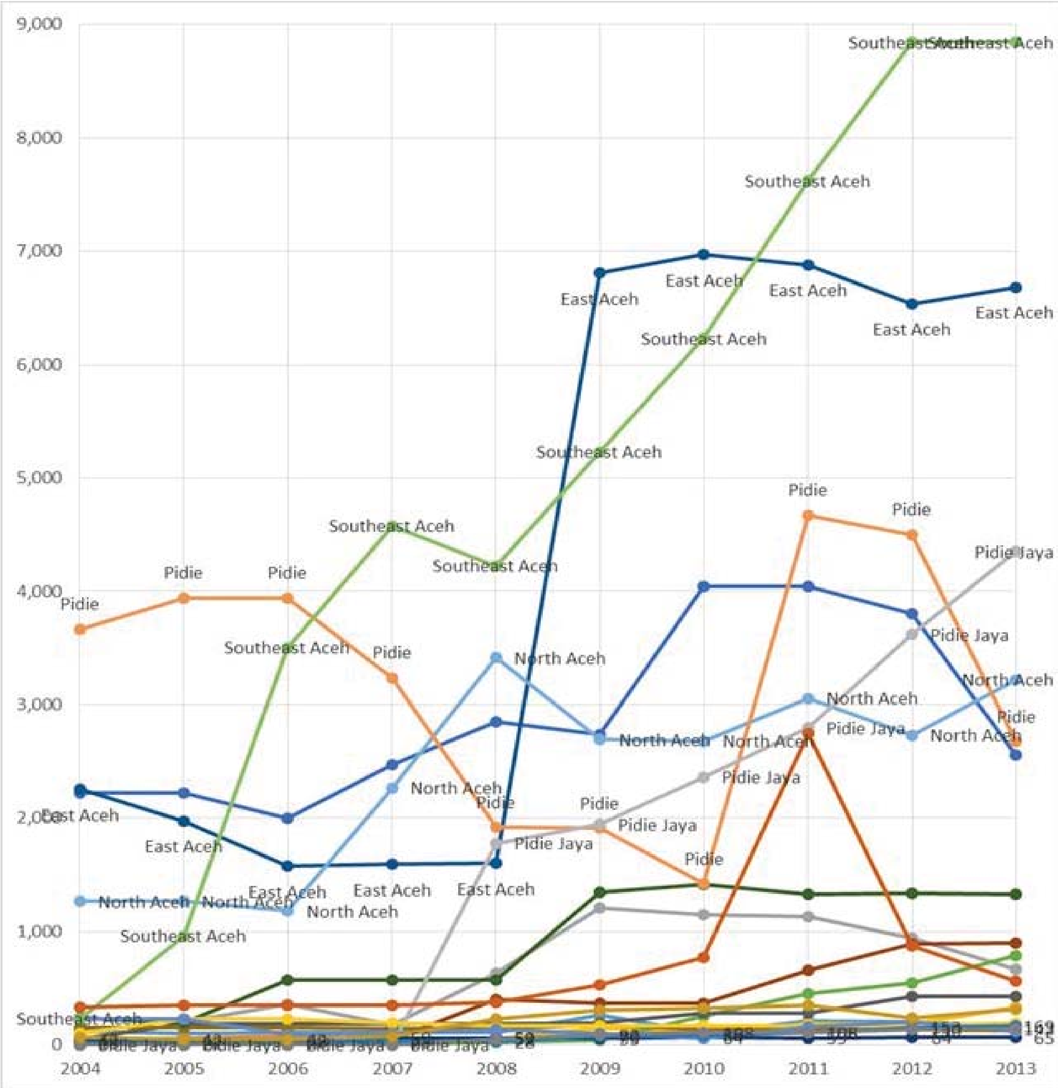


Figure IV.1. The current state of cocoa production at municipal level [metric ton].

Looking at Figure IV.1, there is an unstable production in every municipal in Aceh, indicating no sustainable system throughout the industry. Besides, there is a significant gap between municipals with high productions and ones with quite less productions. The names of five municipals with biggest productions are shown.

Besides production, the current state of coca industry may also be seen from the land use, particularly those of cocoa plantations. Planted areas during the last 10 years are exhibited in Figure IV.2. Looking at the figure, the growth of plantation area in Aceh is arguably stagnant. However, five municipals with widest plantation areas, *i.e.* Southeast Aceh, Pidie Jaya, East Aceh, Pidie, and North Aceh, are the same with ones that have highest productions. In other words, these municipals are quite dominant within Aceh cocoa industry, hence have a potential to strongly influence the entire industry. In contrast, municipals with quite narrower areas have insignificant production growths, meaning that they are in the middle of adding area before going to pursue high production rate.

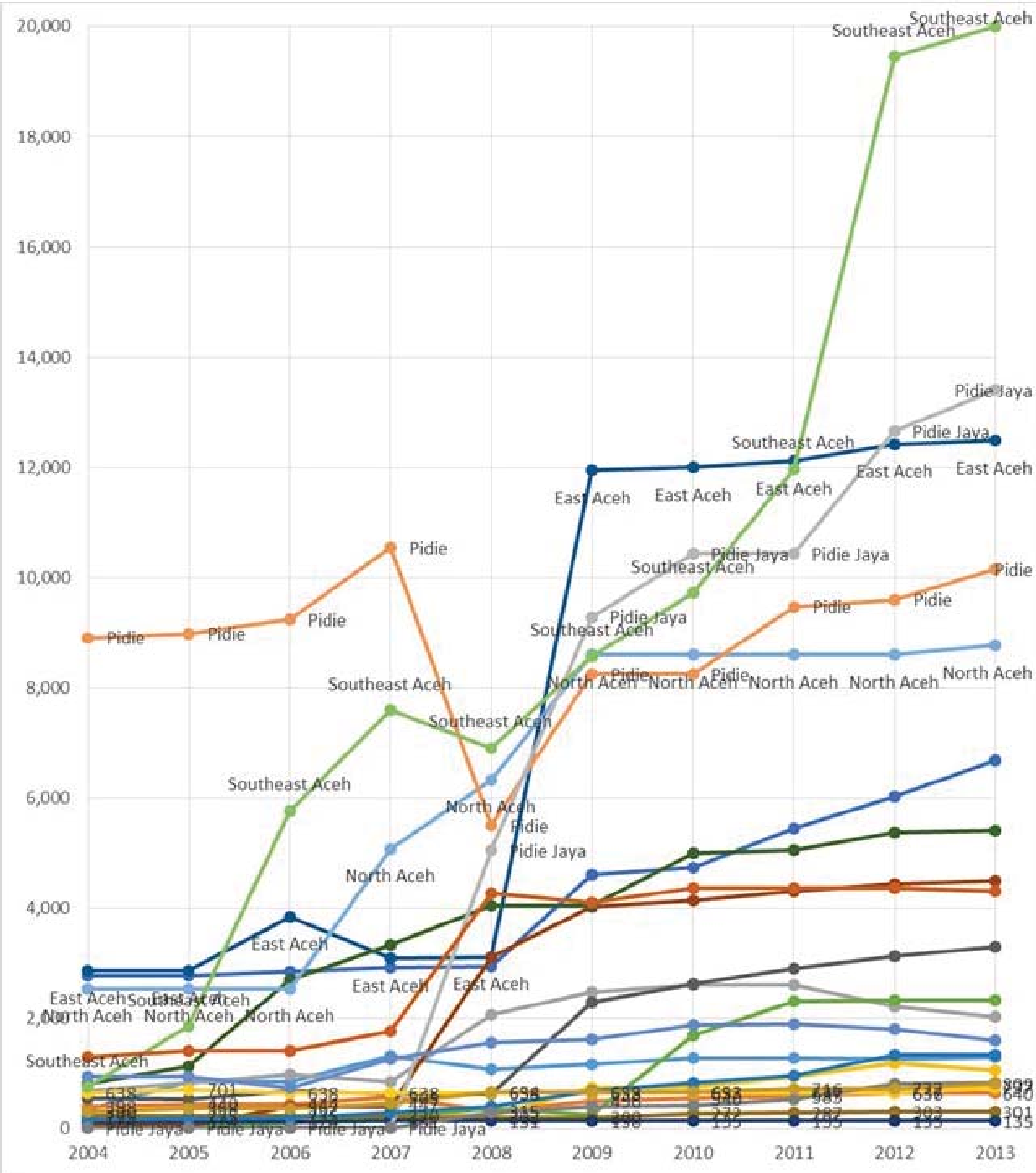


Figure IV.2. The current state of cocoa plantation area at municipal level [ha].

Table IV.1. Five municipals with the highest production [metric ton]

Municipal		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Southeast Aceh	232	960	3,503	4,578	4,227	5,230	6,230	7,622	8,843	8,843
2	East Aceh	2,254	1,974	1,578	1,593	1,599	6,808	6,972	6,881	6,536	6,684
3	Pidie Jaya	-	-	-	-	1,779	1,946	2,362	2,795	3,619	4,349
4	North Aceh	1,268	1,268	1,179	2,268	3,412	2,692	2,680	3,056	2,730	3,222
5	Pidie	3,666	3,941	3,941	3,239	1,920	1,911	1,421	4,674	4,499	2,674

Looking at Figure IV.1 and IV.2, it is promising to distinguish the characteristics of cocoa industry in Aceh by looking at two different groups. The first group consists of municipals with the highest cocoa productions, while the second one is covers those with the lowest production. It is to ensure the reflection of the whole industry, emphasizing a holistic analysis over different types of municipals with different influences toward the entire industry, and pursuing a deeper investigation due to generally defined characteristics of municipals being investigated. Furthermore, those two groups might be distinguished by looking at the general goal in pursuit. Looking at the five municipals with biggest production and widest plantation area, there is an arguably clear sense, in which municipals with high confidence against the market should focus on production rather than plantation area. In other words, they have to put stronger attention on increasing production per hectare. Hence, industrial characteristics among those kinds of municipals requires a careful look on their production rate (Table IV.1), by also considering their production average (Table IV.2). On the other hand, production data and plantation data deliver different lowest five ranks. Based on production data, the five municipals with lowest production are Aceh Jaya, Subussalam, Langsa, Simeulue, and Lhokseumawe; however, based on plantation data the five municipals with narrowest plantations are West Aceh, Sabang, Aceh Singkil, Langsa, and Lhokseumawe. As aforementioned, such a kind of municipals tends to pursue added area rather than production rate. Hence, characteristics of the second group towards the industry are largely based on plantation data, but without completely ignoring production data. The plantation data for the five municipals with narrowest area are exhibited in Table IV.3, and their production average in Table IV.4.

Table IV.2. The production average of the five municipals with highest production [kg/ha]

	Municipal	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Southeast Aceh	309.75	519.20	607.74	603.40	612.08	610.34	640.75	636.76	454.56	442.28
2	East Aceh	787.29	689.49	411.04	515.53	512.99	570.23	581.10	568.30	526.42	535.41
3	Pidie Jaya	-	-	-	-	352.42	209.77	226.40	267.90	286.00	324.46
4	North Aceh	500.59	500.59	465.64	446.72	539.28	312.91	311.52	355.22	317.33	367.72
5	Pidie	411.63	438.82	426.98	307.39	349.41	231.72	172.31	493.87	468.69	263.45

Looking at Table IV.1, Table IV.2, Figure IV.1, and Figure IV.2, Southeast Aceh comes out from the competition to have biggest production rate with a quite wide margin, including a sharp growing of either production rate or plantation; however, it is ranked at the second position in terms of production average. Municipal with the second biggest production, East Aceh, also offers big gap to the third rank. Besides, it achieves the first rank in terms of production average. However, cocoa industry within East Aceh has entered a saturated phase, in which neither its production rate nor plantation area is growing anymore, by which it has been passed by Pidie Jaya in terms of plantation area. Next, municipal ranked the third, Pidie Jaya, shows a promising growth in terms of either production or plantation area. In 2013, it has passed Pidie and North Aceh for being the third biggest production. Besides, it has become a municipal with the second widest plantation area, passing East Aceh. After Pidie, municipal ranked the fourth, North Aceh, is slowly grown. It looks like having a difficulty to increase its production due to a saturated growth of plantation area. Then, Pidie Jaya, the direct neighbor of Pidie, is struggling with its production. Having a steady growth of plantation area, it cannot keep the pace up with a proper growth of production. In fact, it could not maintain the huge production growth it has ever experienced during 2010-2011. However, compared to other five bests Pidie, alongside Pidie Jaya, has the most promising characteristics. These two neighbors have a steady growth of plantation area. Actually, Southeast Aceh has the highest possibility to be the research focus from the first group; however, it has an apparently separated supply chain system from other municipals, which will be explained later. In other words, Pidie and Pidie Jaya offer an exemplary experience of municipals among the five toppest. Among these two, Pidie Jaya shows a better situation by considering its steady growth in either production scale and plantation area. It has become a municipal in Aceh to be able to manage its cocoa industry. Thus, Pidie Jaya is stated as an effective influencing driver among municipals with highest production the entire Aceh cocoa industry.

Table IV.3. Five municipals with the narrowest plantation area [ha]

Municipal		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
19	West Aceh	300	368	367	447	654	653	653	716	722	809
20	Sabang	638	701	638	638	638	638	637	637	637	737
21	Aceh Singkil	398	440	444	565	315	496	540	585	636	640
22	Langsa	225	225	225	220	202	200	272	287	303	301
23	Lhokseumawe	124	124	124	131	131	130	135	135	135	135

Looking at Table IV.3, IV.4, Figure IV.1 and IV.2, Lhokseumawe has the lowest cocoa production and narrowest plantation area; however, it has a promising production average. Despite the prominence, these statistics indicate quite peculiar data, indicating false governmental statistics for a municipal with an insignificant influence to the province. The situation also occurs over Sabang, the fourth ranked from the bottom, in which its plantation data and production average indicate virtually no change over years. Despite a big jump in terms of plantation area during 2012-2013, it is unlikely the case, considering a strong stagnancy over previous years. Next, the second bottom ranked, Langsa, has a strange record during early years during period under review. An exactly the same production average is unlikely to happen. Later, it grew a bit for the last 5 years; however, it apparently has a very low potential for being serious in managing its cocoa industry. Afterwards, Aceh Singkil achieves the third ranking from the bottom. It has a steady growth of plantation area for the last 5 years. Actually, it is considerably better compared to a sudden decrease of area during 2007-2008. Before the decrease, it had another steady increase. However, Aceh Singkil offers a quite low total production and production average. It has a potential but quite weak to be an influencing force over cocoa industry among municipals with narrowest plantation area. Then, West Aceh comes at the fifth bottom ranked. The municipal shows a steady increase of plantation area in the last 10 years. Besides, it is not included among five municipals with the lowest production. In addition, it shows a turning back during 2005-2007 in terms of production average, indicating a successful improvement over its cocoa industry. Thus, among five municipals with narrowest plantation area, West Aceh offers a strong potential as an effective influencing driver among municipals with a weaker local cocoa industry.

Table IV.4. The production average of the five municipals with narrowest plantation area [kg/ha]

	Municipal	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
19	West Aceh	220.00	130.43	122.62	174.50	348.62	468.61	500.77	488.83	325.48	391.84
20	Sabang	153.61	329.53	362.07	310.34	269.59	269.59	270.02	270.02	270.02	261.87
21	Aceh Singkil	70.35	131.82	166.67	92.04	155.56	161.29	157.41	182.91	231.13	262.50
22	Langsa	666.67	666.67	666.67	659.09	702.97	870.00	481.62	459.93	435.64	418.60
23	Lhokseumawe	338.71	338.71	338.71	450.38	450.38	423.08	474.07	437.04	474.07	481.48

IV.1.2 The cocoa industry as a networked supply chain

Despite the facts in which Pidie Jaya and West Aceh are the influencing drivers of the cocoa industry in Aceh, these two municipals still conduct their cocoa industry within Aceh supply-chain, meaning that their activities cannot be separated from the activities of others. Still, the focus is useful to make assumptions in later research stages. In particular, these assumptions can support to produce a clearer sensitivity analysis throughout the industry. Furthermore, interconnection between municipals within the supply chain of cocoa industry in Aceh must be mapped to establish an understanding over the whole system. In general, cocoa industry in Indonesia can be distinguished into two different purposes, *i.e.* export and domestic consumption (Figure IV.3). For overseas consumption, farmers sell their dried cocoa to either collectors or local traders; however, in the end any collector would further sell the beans to local traders. After that, local traders would sell to exporters, who would take care of any export-related matter. On the other hand, for domestic consumption dried cocoa beans are sold to collectors and local traders. The later would then further sell the beans to local processors, producing early products of cocoa beans. Then, those processors sell their products to local manufacturers for being processed into consumer products. Then, the final products are sold to domestic market for being consumed.

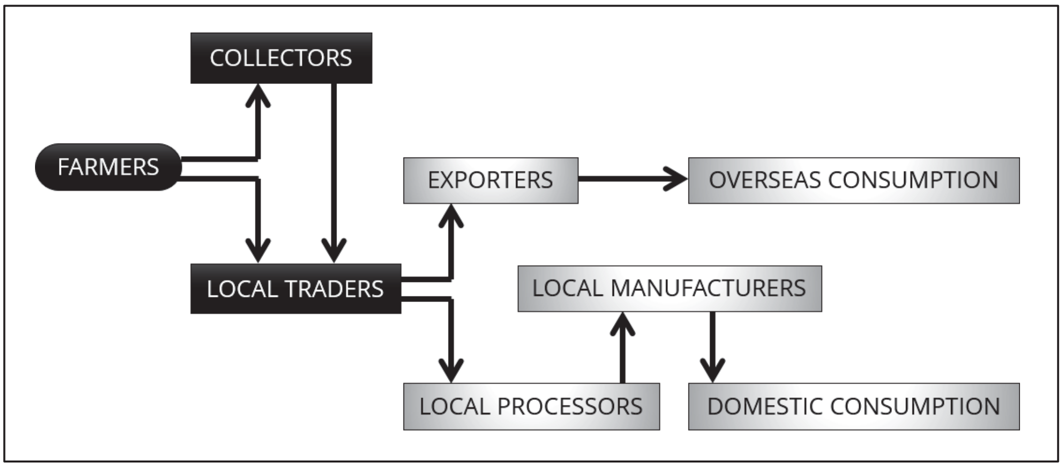


Figure IV.3. General scheme of Indonesian cocoa supply chain.

Within national supply-chain, several stakeholders exist at local/regional level, *i.e.* farmers, collectors, and local traders (Figure IV.3, black boxes). In Aceh, the main purpose of cocoa production is for being exported, hence a mapping on these three stakeholders plus an export gathering center is necessary. Within Aceh cocoa supply chain, these stakeholders are distinguished into three different geographical separations, *i.e.* cacao sources, transits, and export gathering point (Figure IV.4). Cacao sources (S) refer to farmers, particularly their plantation area, from which dried cocoa beans are first taken. Next, transit (T) means collectors and any intermediary (middlemen) that must be passed through to sell dried cocoa beans. Then, Export gathering point (G) refers to the point to which dried cocoa beans are collected. It is the highest stakeholder within Aceh regional cocoa supply chain.

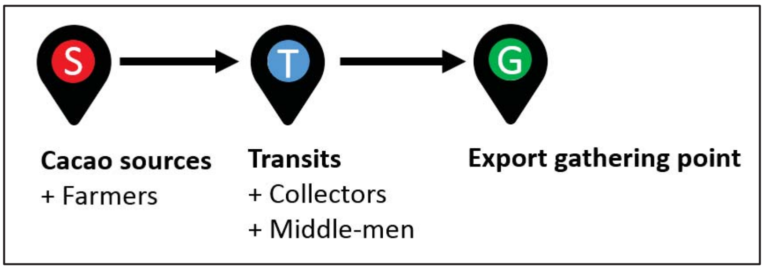


Figure IV.4. General scheme of Aceh cocoa supply-chain for export purpose.

Based on these understandings, supply-chain of cocoa industry in Aceh is mapped. The position of every stakeholder and its municipal is directly surveyed on the field, including their possible connections. A data gathering on the field successfully detects the position of nine of them, and one additional transit point (Bereunun). Apparently, the strongest influencing driver among highest-producing municipals (Pidie Jaya) is located at the same regency with the export gathering point, while the influencing driver among weakest-producing regions (West Aceh) is located within 2-4 stages reach of its supply chain.

Based on the general map (Figure IV.5), a detailed overview of supply chain is developed (Figure IV.6). The involved municipals and transits are Banda Aceh (A), Pidie (B), Bereunun (C), Pidie Jaya (D), Bireun (E), North Aceh (F), East Aceh (G), Central Aceh (H), West Aceh (I) and Southeast Aceh (J). Apparently, Southeast Aceh (J) has no direct correlation with the entire cocoa industry in Aceh. It is connected to cocoa supply chain in North Sumatra, a neighborhood province of Aceh. Despite its existence as a municipal in Aceh, it, therefore, will not be included in any further analysis.

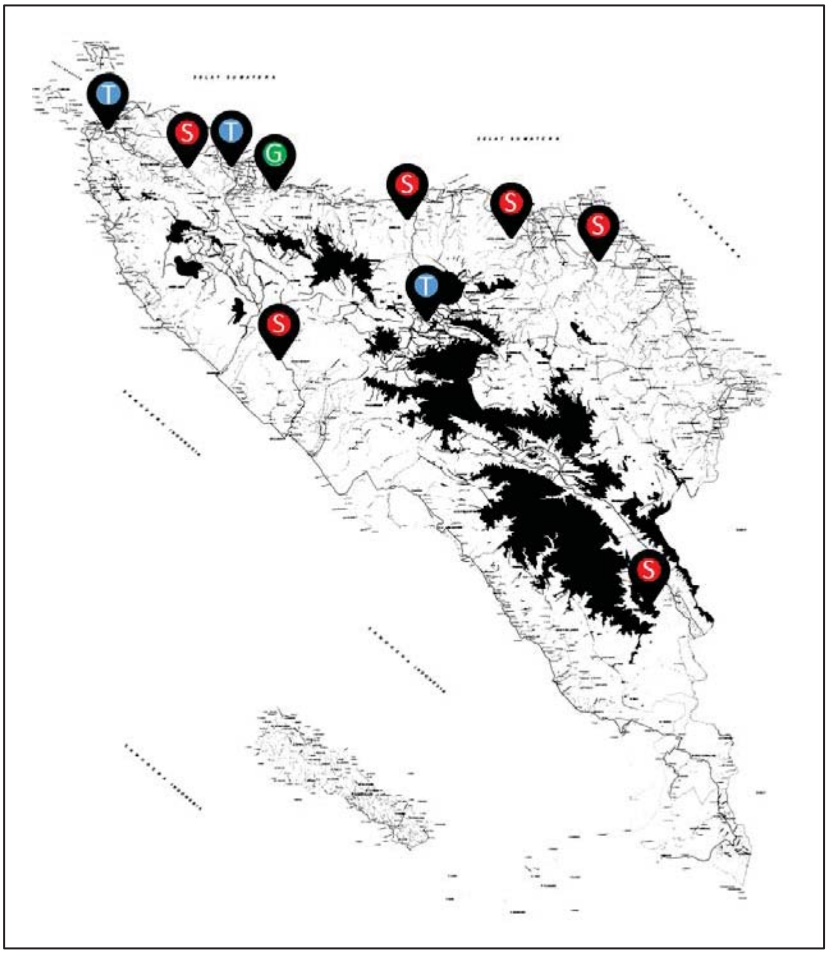


Figure IV.5. The position of stakeholders within cocoa supply chain in Aceh.

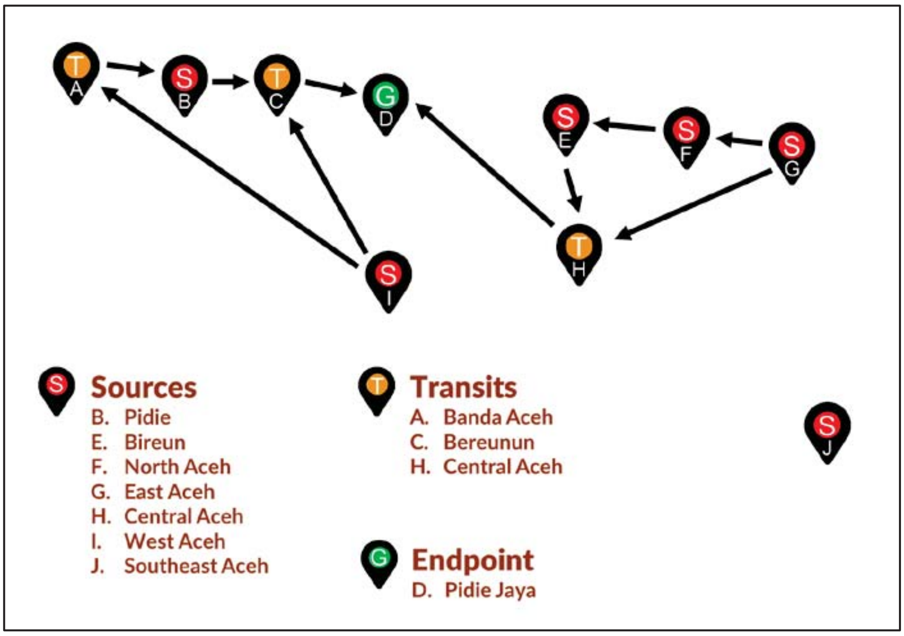


Figure IV.6. Existing positions and movements in the supply-chain.

Furthermore, the position of Pidie Jaya in the same place with the export gathering point might be an advantage for farmers in the municipal; however, it might not be fit for being the general characteristics of highest cocoa-producing municipals. The same place diminishes any consideration on distribution travel, economic restrictions, environmental emissions, *etc*., which would bias any produced strategy or scenario for being taken by other municipals. Therefore, another municipal from the first group, five municipals with the highest production, is required to see the more complete characteristics of an influencing driver. Looking at previous explanations, Pidie (B) is becoming the second most promising municipal within the first group. Based on the map of cocoa supply chain in Aceh (Figure IV.5 and IV.6), it is within two stages reach to the export gathering point (G), making it possible to analyze things normally.

Table IV.5. Distance between origin-destination (O/D) [km]

O/D	A	B	C	D	E	F	G	H	I	J	Shortest Route
A		149									
B			43	93.9							B-D via C
C				50.9							
D											
E				338				133			E-D via H
F				449	111						F-D via E-H
G				415		163		210			G-D via H
H				205							
I	240		144	194.9							I-D via C
J											

*) blue boxes → from a source (S) to export point (G); black boxes → the same place; red boxes → inaccessible routes

Within the whole supply chain, multiple connections mean geographical distances. A measurement on the distance is conducted directly on the field to investigate the normal kilometers a vehicle must reach to transport cocoa beans from one to another place. The measurement is taken about five times by using a pick-up car, as collectors/local traders usually did. The results of distance measurement are exhibited in Table IV.5. Looking at the table, transportation from Pidie (B) to export point (D) is within 93.9 km reach via Bereunun (C) as its shortest route, whereas from West Aceh (I) to the end point (D) is within 194.9 km reach by using a pick-up car via Bereunun (C) as the shortest route. Distance from other sources are 338 km (Bireun via Central Aceh), 449 km (North Aceh via Central Aceh), and 415 km (East Aceh via Central Aceh).

Table IV.6. Required time between origin-destination [minutes]

O/D	A	B	C	D	E	F	G	H	I	J	Speed [km/h]
A		170									
B			63	120							46.95
C				57							
D											
E				486				209			41.73
F				629	143						42.83
G				583		183		306			42.71
H				277							
I	282		199	256							45.68
J											

*) blue boxes → from a source (S) to export point (G); black boxes → the same place; red boxes → inaccessible routes

At the same time, a measurement is directly taken on the field to investigate the required normal time to reach those distances (Figure IV.5). The time measurement is exhibited in Table IV.6. Due to topographical differences between routes, the speed of the tested pick-up car is in fact vary. The variety is also reflected to the variety of required time. In average, the speed is varied between 41-47 km/h, with the highest speed occurs between Pidie (B) to the end (D), with an average of 46.95 km/h. It requires 120 minutes. On the other hand, transportation between West Aceh (I) to the export point (D) requires 256 minutes, with an average speed of 45.68 km/h. These considerably higher speeds might occur due to the easier topography between origin and destination, making it possible to drive with faster transportation speed. Then, the required time for other sources are 486 minutes (Bireun, with 41.73 km/h average speed), 629 minutes (North Aceh, 42.83 km/h), and 583 minutes (East Aceh, 42.71 km/h).

Then, the cost paid for transportation from each source is different by considering some of these following reasons. First, part of the cost is paid for covering driver's additional personal expense, *e.g.* cigarettes, food, drink, etc. Second, there is a fixed cost for one transportation, influencing the total cost. Besides, the fixed cost is differently demanded by different driver, so it is in fact vary. Third, as aforementioned there are topographical differences between routes, so part of the cost paid for primary things, e.g. fuel, maintenance, etc., are different. Considering these reasons, cost per one distance unit is decided by the real cost demanded by driver in a common situation (Table IV.7). The real cost is gathered by averaging a variety of cost from a source during the experiment on distance and time, i.e. about 5 times trials for each source, with a normalized amount of transported products of every fully-occupied car. From those trials, the cost from West Aceh (I) to the export gathering point (D) is Rp 200/km, which produces a total cost of Rp 38,980 per one-time transportation of products occupying one pick-up car. On the other hand, one-time transportation of a full from Pidie (B) to the endpoint (D) costs Rp 563,400. Then, the costs from other sources are Rp 351, 520 (Bireun), Rp 426,550 (North Aceh), and Rp 311,250 (East Aceh).

Table IV.7. Cost spent for transportation between origin-destination [Rp].

O/D	A	B	C	D	E	F	G	H	I	J	Cost [Rp/km]
A											
B				563,400							6,000
C											
D											
E				351,520							1,040
F				426,550							950
G				311,250							750
H											
I				38,980							200
J											

*) blue boxes → from a source (S) to export point (G); black boxes → the same place; red boxes → inaccessible routes

Chapter V MODEL BUILDING
Proposed models and preliminary experiments

V.1 System dynamics model on a singular agent

V.1.1 The dynamic impacts of Appropriate Technology

As explained earlier, the assessment process on an appropriate technology is currently conducted through a static way. It is due to limited resources to do a dynamic analysis, alongside with difficulties to do a dynamic assessment based on a bottom-up technique together with local people. However, the facts that an AT cannot be separated from continuous process happens in local area indicates that assessment on AT requires longer assessment timeframe. If time limitation is arguably non-existence, dynamic analysis becomes the critically-needed answer. Furthermore, following a remarkable notion by Kaplinsky (2011), Sianipar *et al.* (2013b) suggests the meaning of technological appropriateness based on a deeper understanding on the practicalities of its concept, intermediating specific-characteristics of an "appropriate" technology to the general-principles of technological "appropriateness", hence emphasizing both strong conceptual and practical levels. They propose the levels of appropriateness stated as basically (technical and economic), environmentally, and socially appropriate, as a means to give a clearer view on the resonances between a specified technology to contextual matters in a specified location. On the other hand, Lucena *et al.* (2010) highlights 21st century's global concerns on environmental issues throughout related activities of a technological solution. Besides social impacts, technology development needs to pay enough attention on potential impacts imposed by AT-related activities in the frame of continuous interactions between the members of specified community to surrounding nature. Looking at those explanations, the dynamic assessment on AT is potential to be started on economic and environmental impacts by considering that the technical aspects of an AT is embedded in the technology, while the technical aspects of supply chain emerges within the chain itself. Besides, social impacts require more social-qualitative approach to precisely capture its intention.

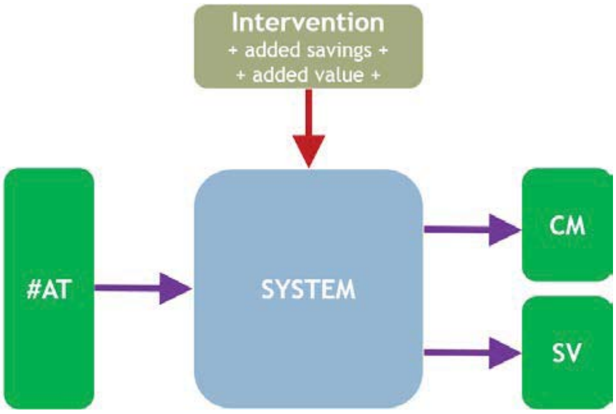


Figure V.1. Scope of the early model.

V.1.2 Scope of the early model

The model of economics and environmental assessment on AT begins with the overview of its idea. In spite of the causal loop emphasized by system dynamics approach, the overview (Figure V.1) is required to understand the initial input and expected output in the assessment model, including potential interventions to improve process as a means to change any expected outcome(s). In this study, the only initial input is the number of AT (Figure V.1, *#AT*). It refers to available technologies at one observation timeframe used to process the commodities (cocoa beans). The number of AT affects the quantity of improved dried cocoa beans compared to conventionally dried beans in a total number of harvested wet beans per time unit. On the other side, the observed outcomes are savings (Figure V.1, *SV*) and emission per unit mass dried cocoa beans (Figure V.1, *CM*). The observed savings is intended as the one from which farmers take fund for expanding the use of cocoa drying technology, or in other words to increase the number of available technologies. Savings is measured in Indonesian currency (Rp). Besides, emission per unit mass refers to the environmental impact expressed in CO_2e unit imposed to the environment due to the use of all available drying technologies in their life-cycle. The imposed impact is then divided equally to the number of dried beans at an observed timeframe to know the emission-equivalent impacts per unit mass of dried cocoa beans.

Looking at the above explanation, the savings (*SV*) causes further increase of the number of available AT (*#AT*) if and only if there is a requirement to make additional drying technology and at the same time there is enough fund to do the construction process. However, the environmental impact imposed per unit mass of dried cocoa beans (*CM*) acts as a target function to which calculation process in the system needs to pursue for. Therefore, at least there are two intervention possibly applied to the system. The first intervention is on the ratio of savings taken from income collected after all dried beans are sold per unit timeframe. The ratio of added savings can be suggested to farmers as means to encourage them for increasing the number of available technologies as soon as there is adequate amount of funds. Furthermore, there is a chance to negotiate with buyers in order to increase the added value for improved dried cocoa beans that have higher quality than the conventionally dried beans. The negotiated added value hence becomes an intervention to the observed system.

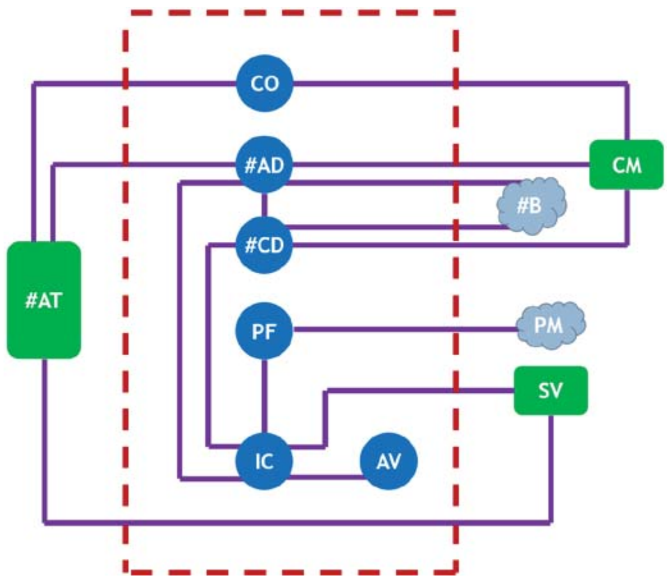


Figure V.2.	System boundary.

V.1.3 System boundary

After the scope of the model is firmly established and any initial input, expected outputs, and possible intervention are defined, the system as the model's core construct needs to be expanded to explore required information to process inputs to become outputs, including hook points of intervention. The information are expressed as desired variables in a stated boundary. Figure V.2 exhibits the scheme of system boundary. There are eight variables both in and outside the observed boundary. The indigenous variables (Figure V.2, blue circles) consist of total emission (*CO*), the amount of improved dried cocoa beans (*#AD*), the amount of conventionally dried beans (*#CD*), commodity prices at farmers' level (*PF*), farmers' income (*IC*), and added value (*AV*). On the other hand, there are two exogenous variables (Figure V.2, grey clouds) stated as uncontrollable ones: the total amount of harvested beans (*#B*), and commodity prices at its market (*PM*).

The first endogenous variable, total emission (*CO*), refers to the total emission-equivalent impacts imposed by all available technologies throughout their life-cycle. The second one, improved dried cocoa beans (*#AD*), is posited as the indicator of how much cocoa beans are dried using all available cocoa drying technologies at an observed timeframe. The number of conventionally dried beans (*#CD*) are then inserted as the rest amount of harvested beans (*#B*) which have not been dried using the technologies. Next, commodity prices at farmers' level (*PF*) is the base price of dried cocoa beans inserted from an exogenous variable market price (*PM*). After that, added value (*AV*) is the additional amount of money added to the base price for farmers (*PF*) as the consequences of improved quality of dried cocoa beans due to the use of drying technologies. Then, the last endogenous variable is income (*IC*) which expresses an amount of financial benefits gathered from the selling of all dried cocoa beans at an observed timeframe, both from conventionally dried beans (*#CD*) and improved dried ones (*#AD*).

V.1.4 Causal-Loops Diagram (CLD)

Based on the explanation of model scope and system boundary, the basic form of system dynamics model can be established. Looking at Figure V.1 and Figure V.2, there are two causal diagrams can be constructed to express economic dynamics for measuring savings (Figure V.2, *SV*), and environmental dynamics to indicate emission-equivalent impacts imposed per unit mass (Figure V.2, *CM*). Furthermore, the form of causal diagram for economic dynamics (Figure V.3) has looped feedbacks as the consequences of new numbers of available technologies due to required additional drying capacity and available funds/savings. On the other hand, the form of causal diagram for environmental dynamics (Figure V.4) has a limited direct feedback due to the intended measurement unit. As previously indicated in Figure V.2, the amount of improved dried cocoa beans and conventionally dried beans become the connecting points between those two diagrams. Besides, the decreasing number of available technologies due to the end of life-cycle becomes the balancing loop for both diagrams.

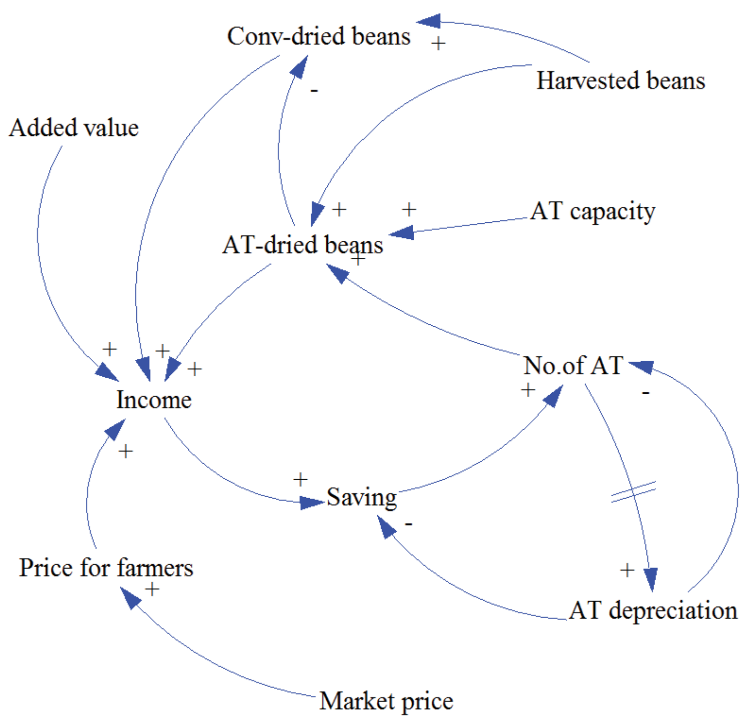


Figure V.3. Causal-loop relationships (economics).

In the causal loop diagram for measuring economic dynamics (Figure V.3), there are some causal connections between variables. When there is an increasing amount of harvested cocoa beans (Kilogram), the amount of both improved (Kg/month) and conventionally dried beans (Kg/month) will also increase; however, if the number of available AT increases, the amount of improved dried beans will increase, and then it decreases the amount of conventionally dried ones. The similar condition occurs when drying capacity of each AT (Kg/unit/month) increases. From both amount of dried beans, income (Rp/month) will increase. Besides, two endogenous variables "added value" (Rp/Kg) and "price for farmers" (Rp/Kg) are positively correlated to the amount of generated income. After that, the increase of income will increase savings (Rp). From such available funds, the number of ATs can be increased. However, each AT has its lifetime limit, so that the depreciation (36 months/unit) is positively correlated from the number of AT, and negatively correlated to savings due to required replacement of each broken AT (Rp/unit).

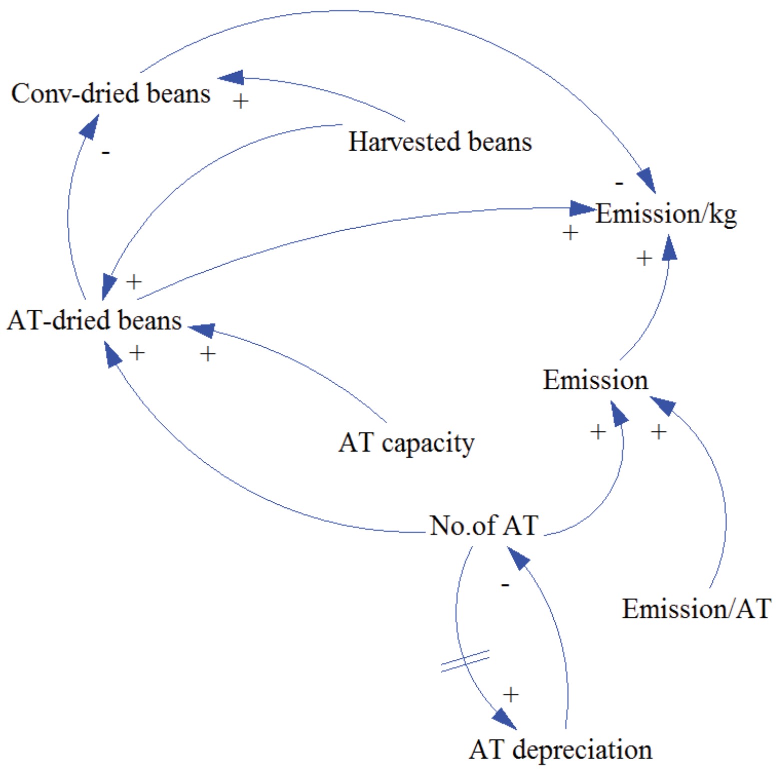


Figure V.4. Causal-loop one-way relationships (environmental).

On the other hand, in the causal diagram for indicating environmental impacts (Figure V.4) there are some causal connections with one-way influences toward emission-equivalent per unit mass as the target function. Such diagram starts from the same initial input: the number of available technologies. Such number alongside drying capacity of each AT are positively correlated to the amount of improved dried cocoa beans. Besides, the amount of conventionally dried beans is negatively correlated from the amount of AT-dried beans; however, the increase of harvested beans is positively correlated to those amounts. On the other end, emission-equivalent per AT (CO_2e/unit) and the total number of available AT (unit) are positively correlated to the emission-equivalent total of all available technologies (CO_2e). Next, if the total emission increases, distributed emission-equivalent per unit mass of dried cocoa beans (CO2e/Kg) will increase. Moreover, while the amount of AT dried beans increases alongside the amount of emission-equivalent per unit mass, the increase of conventionally dried beans will decrease the distributed impacts per unit mass. Then, AT depreciation (36 months/unit) becomes the balancing loop through the delayed increase of depreciation due to the increase of the number of AT and the direct decrease on the number of available technologies after a given period of lifetime.

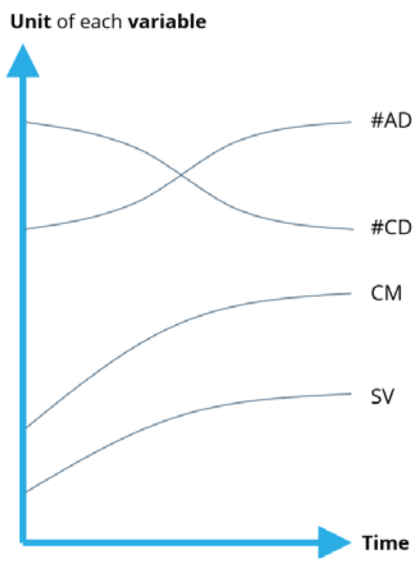


Figure V.5. Expected Behavior Over-Time (BOT).

By looking at the causal diagrams of both economics (Figure V.3) and environmental dynamics (Figure V.4), the behaviors of some important variables are possible to be predicted. The diagram of expected Behavior Over-Time (Expected BOT, Figure V.5) exhibits predictions on four variables: the amount of improved dried beans (*#AD*), the amount of conventionally dried beans (*#CD*), distributed emission-equivalent per unit mass of dried cocoa beans (*CM*), and the amount of savings for replacing and adding a new AT (*SV*). Between *#AD* and *#CD*, there is a hooked understanding because the sum of those two will always produce the total amount of harvested beans. Hence, the BOT of *#AD* and *#CD* are negatively correlated, and are maintained by the total amount of harvested beans to avoid excessive number of additional technologies due to the decreasing value of *#CD* when *#AD* increases. On the other hand, *CM* and *SV* tend to increase when *#AD* increases. Their behaviors are similar because they rely on the same critical parameters that are *#AD* and *#CD*. From those early understanding on expected BOT, later modeling process can be set to test the configuration of intervention(s) by which expected BOT (Figure V.5) can be similarly performed.

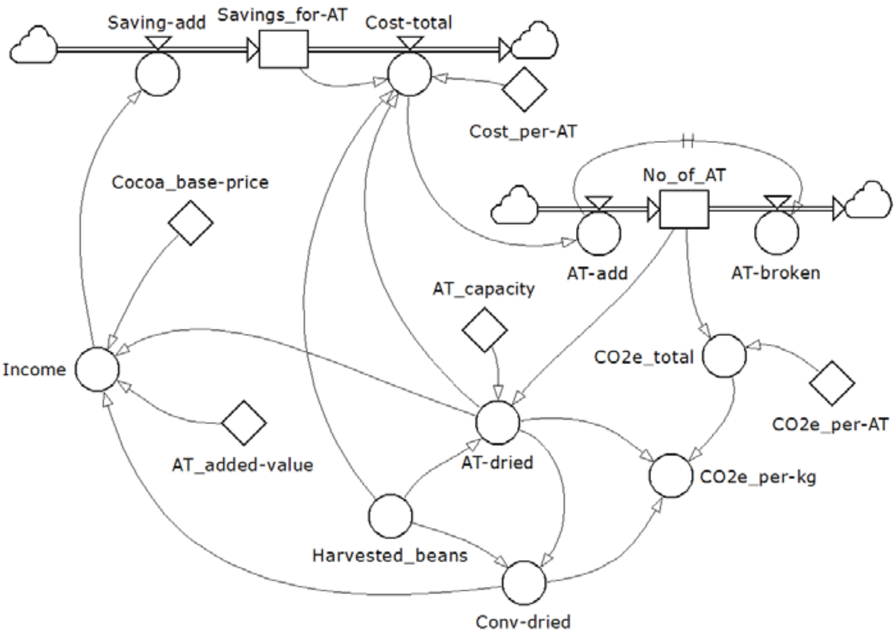


Figure V.6. Basic Stock-and-Flow Diagram (SFD).

V.1.5 Basic Stock-and-Flow diagram (SFD)

Based on causal diagrams exhibited in Figure V.3 and Figure V.4, Stock-and-Flow Diagram (SFD) can be constructed as the real form of System Dynamics model. The SFD model in this study (Figure V.6) is the operational form of combined causal diagrams between causal loop of economic dynamics (Figure V.3) and causal one-way diagram of environmental dynamics (Figure V.4). The stocks in the model are posited to express the amount of savings intended for adding and replacing AT (*Savings_for-AT*) and the number of available AT (*No_of_AT*) in an observed timeframe (per month). For the *No_of_AT* stock, *AT-add* rate adds the number available AT when there is an additional or replacement technology is available. The addition or replacement is related to the availability of savings (stock of *Savings_for-AT*) which is reduced by the total cost (*Cost-total*) paid for constructing a new AT. Next, the stock *No_of_AT* is reduced when an available technology has reached its lifetime limit (36 months). Then, *Savings_for-AT* is added per month by a ratio of income (*Income*) generated by the selling of dried cocoa beans. Moreover, the initial amount of *No_of_AT* is 1 [unit] and *Savings_for-AT* is 0 [Rp]. Besides, the drying capacity of an AT is 20 [Kg/month], while emission equivalent per AT throughout its lifetime is 11.861 [KgCO_2e] which is then divided by the length of lifetime of an AT (36 [months]). Then, in calculating *Cost-total* the *Cost_per-AT* is fixed at 1,991,350 [Rp/unit].

In this SFD, the total amount of harvested beans is posited as auxiliary despite its origin as an exogenous variable and uncontrollable input. It is intended to do a calculable amount of both improved and conventionally dried cocoa beans. The variable *Harvested_beans* is fixed at the amount of 1783.333 [Kg/month] by equally distributing the total amount of harvested cocoa beans in both peak and low seasons to every month in a year (12 [months]). Also, *Cocoa_base-price* is basically derived from uncontrollable market price (Figure V.2, *PM*), yet in this SFD it is fixed at 20,000 [Rp/Kg] to help the calculation of income. Besides, the *AT_added-*

value is fixed at 4,000 [Rp/Kg]. Another important attention needs to be addressed on the SFD model regarding the formulation of income (*Income*).

Income = [(*AT-dried* * 0.37) * (*Cocoa_base-price* + *AT_added-value*)] + [(*Conv-dried* * 0.54) * *Cocoa_base-price*]

After harvested cocoa beans are dried, there is a decrease in mass due to the loss of water moisture during drying process. Ülrich (2009) noted that the rest of mass of conventionally dried cocoa beans is about 54% of original mass when beans are first harvested; however, the observed AT in this study can produce 37% after-drying mass compared to original mass. Thus, the calculation of income has to include those changes in mass. The formula is then perfected by adding *Cocoa_base-price* and *AT_added-value* to the equation. In short, the 37% amount of improved dried cocoa beans is multiplied by the sum of *Cocoa_base-price* and *AT_added-value*, while 54% amount of conventionally dried beans is multiplied by only *Cocoa_base-price*.

V.1.6 Preliminary experiments

After all constants are declared and relationships & equations are clearly stated, experiments can be conducted on the SFD model (Figure V.6) to investigate the influences of possible intervention (Figure V.1). In this experiment, the model is simulated by using these following rules: (1) the Timestep of simulation is fixed at 30 days (1 month) to be consistent with as indicated in many variables in the model; (2) the observation time limit will be 20 years to extend the observation level until long-term scale. Furthermore, due to the first fixed amount on *AT_added-value* (4,000 [Rp/Kg]) the first experiment will be conducted by changing the value of ratio in *Saving-add*. Assuming that the ratio is under 10% of income per month (*Income*), the values are hence set at 0.01 to 0.09 (1% to 9 %).

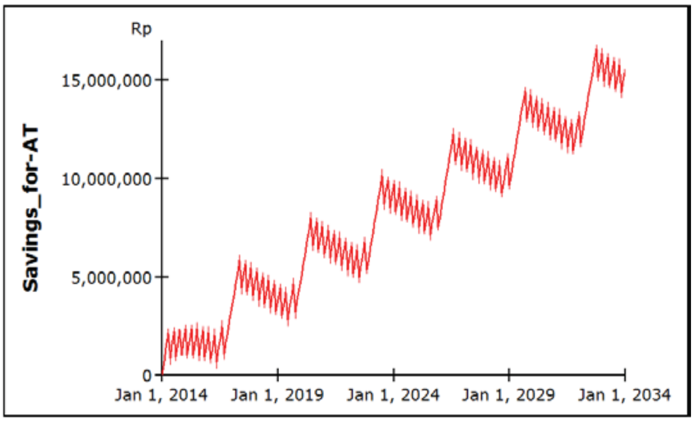


Figure V.7. Accumulated savings.

After some incremental testing, there is a tendency in which the value of *Savings_for-AT* increases yet it is maintained at reasonably low level, meaning that there is a small amount of funds which is kept in saving. The setting for such condition is default (4,000 [Rp/Kg]) for *AT_added-value* and 3.75% for the ratio of *Saving-add* to *Income*. The accumulated savings (Figure V.7) shows a good behavior and in conformance to expected BOT in general. Actually, there are some significant distortions and a turning back every 3 years due to the continuous number of deprecated drying technologies after their lifetime limit; however, in general the increases still in dominance over the reduced amount of savings.

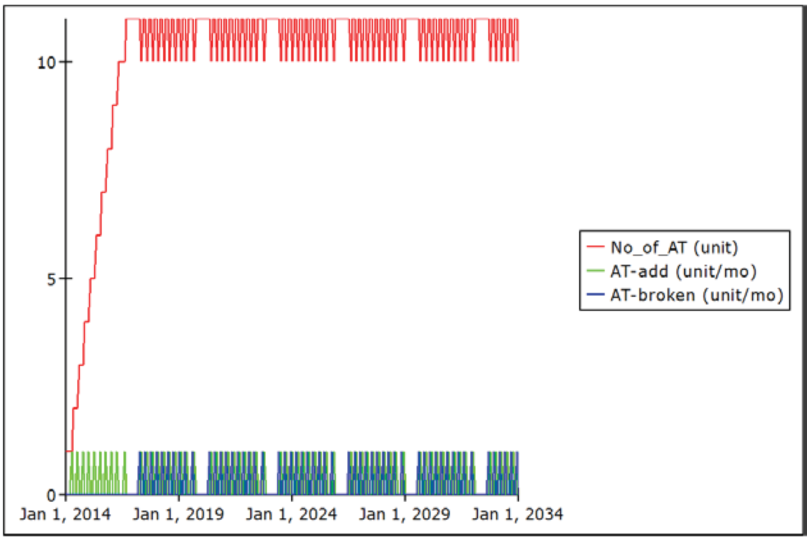


Figure V.8. Number of available technologies.

Following the behavior of accumulated savings, the number of available technologies (Figure V.8) shows a similar pattern. In the beginning of simulation, the number increases at every time available fund is enough to finance the construction of a new AT. The increases continue until all harvested beans can be covered by available technologies. Few months after every 3 years, there are patterns in which replacement of deprecated ATs has to be implemented. The number of AT will decrease for about 1 unit below its maximum level, and increase again one month later. However, the general pattern shows that in almost time the number of AT reaches maximum level, meaning that all amount of harvested cocoa beans in a month can be dried using them. It then delivers maximum income due to the maximum addition of *AT_added-value*.

Looking at Figure V.9 and the behavior of *No_of_AT* (Figure V.8), the amount of emission-equivalent per unit mass is following the changing number of available technologies. The fit changing is possibly caused by the simple calculation of impact at only in the development of AT. Despite the low amount of impacts (4.9-5.4 [gCO_2e/Kg]) at its peak distortive behavior, the environmental impacts hence strongly depend on the changing number of usable ATs.

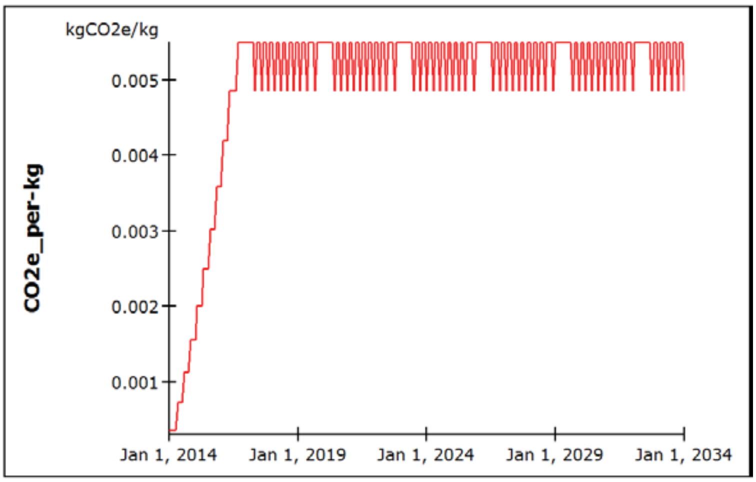


Figure V.9. Emission-equivalent per unit mass.

V.1.7 Simple optimization

Then, the setting of savings ratio from income is fixed to continue the experiment to test the second intervention. The setting is therefore set at 3.75% savings ratio, and previously assumed 4,000 [Rp/Kg] as the maximum level *AT_added-value* is changed to lower level by decreasing 1000 [Rp/Kg] until there is significant change to savings graph. Then, the incremental decrease is set at smaller amount to find the more precise value which can produce savings with less amount but still increases over time.

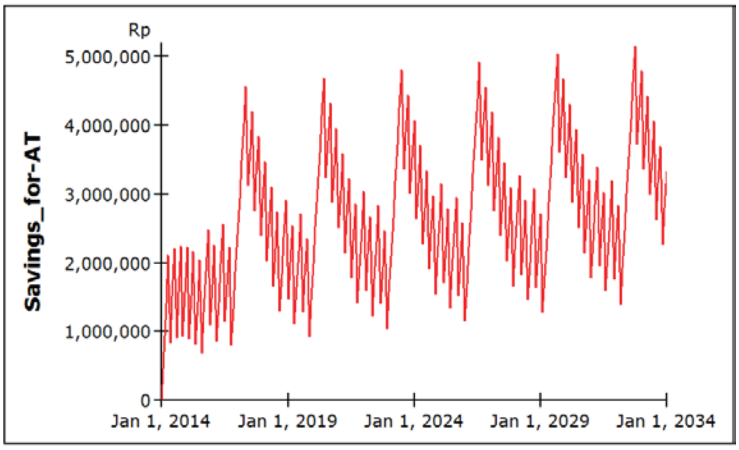


Figure V.10. Accumulated Savings at the optimized value of AT_added-value.

After some repetition, the adequate value of *AT_added-value* to produce lower savings but still maintains the full coverage of drying process on all harvested beans is at 1,750 [Rp/Kg]. The value means that in expanding the number of available technologies, farmers do not need to receive as high as previously defined (4,000 [Rp/Kg]). The new value is enough to add a new additional AT and to replace deprecated drying technology while the level of accumulated savings can be maintained at low level (Figure V.10). By using the new value, the behavior over time of emission-equivalent per unit mass is still the same, and the coverage of drying process can reach maximum (100%) with very similar distortion pattern. In sum, the results show that the first defined value of an endogenous variable

(*AT_value-added* → 4,000 [Rp/Kg]) is quite high compared to later found level (1,750 [Rp/Kg]). The new value can produce very similar behavior of the emission-equivalent per unit mass while the coverage of drying process on harvested beans is maintained at its maximum level. The new value is also potential to be used to put lower limit of negotiation in convincing buyer to give added value for improved dried cocoa beans.

V.2 Pushing a new system: From existing to future

As explained earlier, the current situation of interconnected supply paths within the cocoa industry in Aceh is not so efficient (Figure IV.6). It consists of interrelated paths with an excessive number of stages that sometimes do not make sense in terms of rational transportation and distribution network. For example, transit A (Banda Aceh) does not necessarily act as an effective transit place. It only lengthens transportation time and distribution path from West Aceh (I) to Pidie (B) and later to Pidie Jaya (D). On the other path, Central Aceh (H) acts as another ineffective place as a transit, making transportation time and cost from East Aceh (G), North Aceh (F) and Bireun (E) to get larger without any real rational benefit. In general, it is better to directly connect production sites to end gathering point. If it is not possible, a production node may act as temporary distribution node for farther place. Thus, there is a need to push a redefined state of the cocoa supply chain in Aceh by reducing the number of unnecessary intermediate places (transits).

From the existing system (Figure IV.6), this research aims at pushing a new system of interconnected supply paths in the cocoa industry in Aceh, Indonesia (Figure V.11). At first, the current supply chain network is distinguished into two different parts, *i.e.* West and East. The West section consists of paths covering West Aceh (I), Banda Aceh (A), Pidie (B), Bereunun (C) to end at Pidie Jaya (D). The East section covers path including East Aceh (G), North Aceh (F), Bireun (E), Central Aceh (H) to end at the same gathering point (Pidie Jaya → D). The new system is aimed at gradually removing transits, including Banda Aceh (A), Bereunun (C) and Central Aceh (H). Thus, the new system would have a very simple supply path for each section (Figure V.11). West Aceh (I) as an influencing driver among weakest cocoa-producing regions in Aceh has an opportunity to directly connect to Pidie (B), which is observed as an influencing driver among highest cocoa-producing regions. Their connection would directly be attached to Pidie Jaya (D) as the end point and most influencing cocoa-producing region in the province. On the other side, East section aims at removing Central Aceh (H) as an unnecessary transit. Despite having the same transportation flows between East Aceh (G), North Aceh (F) and Bireun (E), the accumulation of dried and fermented cocoa from those regions at Bireun € would be directly delivered to Pidie Jaya (D) as the export gathering point. Thus, it cuts significant distance, time and cost, while avoiding significant decreases of cocoa quality due to long transportation distance and time.

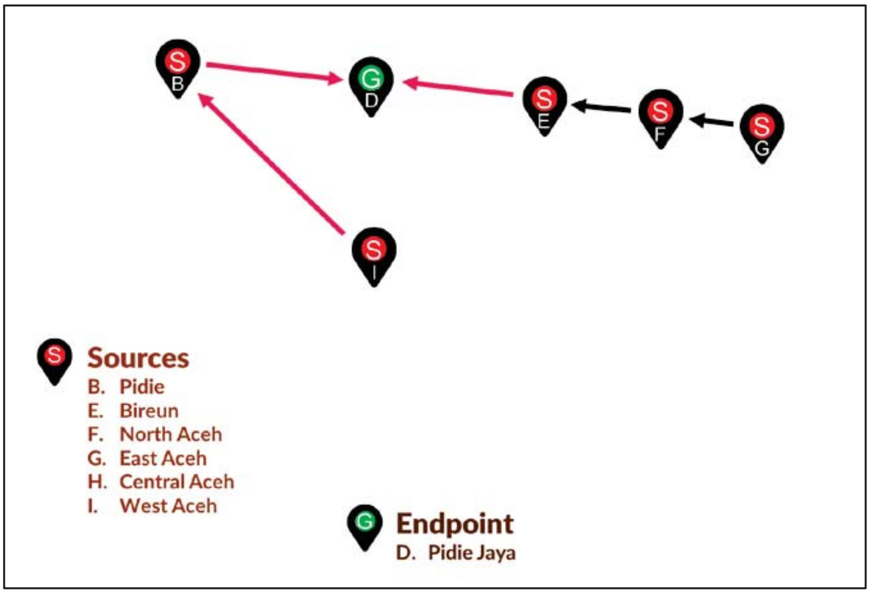


Figure V.11. Future multi-agent network.

V.3 Multi-agent dynamics: The model

V.3.1 Basic transactional supply-demand activities

To push a new system into the cocoa industry in Aceh, Indonesia, it is critical to understand the attributes of basic activities currently undergoing within the industry. In particular, the attributes of activities being observed are those occuring between cocoa producing node/farmers and immediate buyer/intermediary (Figure V.12). First, production node is labeled with an index *i*, while immediate intermediary with index *j*. Immediate intermediary may occur as purely transit region with no production activity, or another cocoa-producing region that acts as temporary distribution node for a farther producing region.

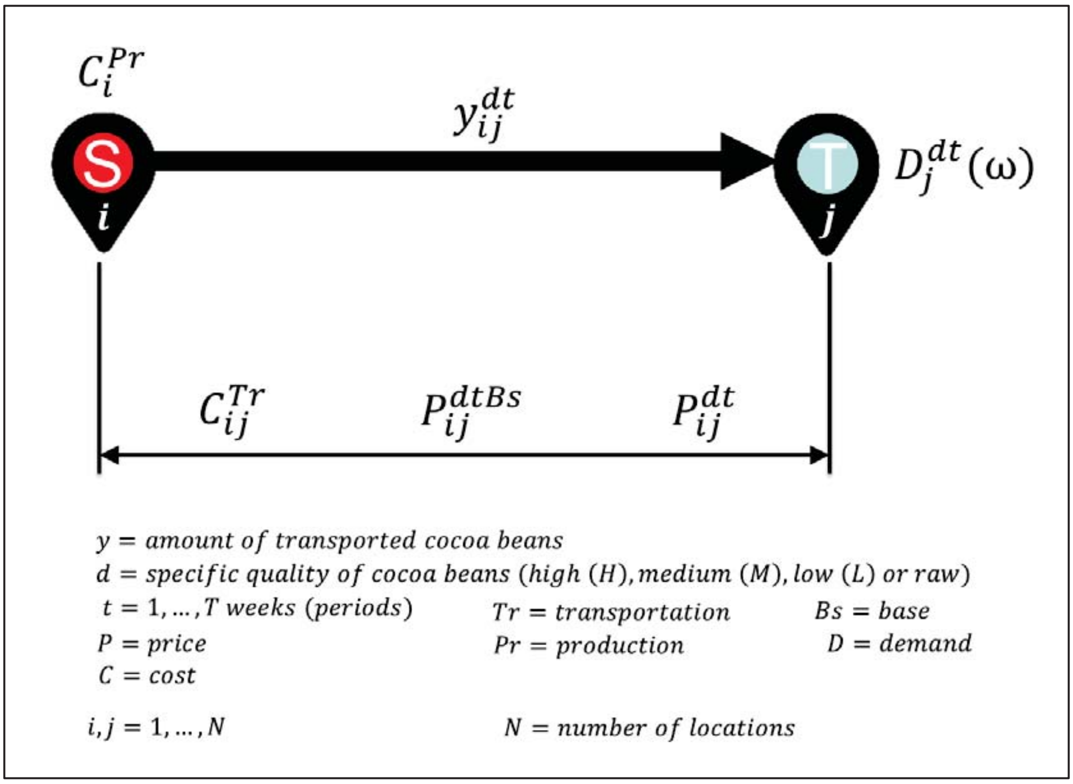


Figure V.12. Basic transactional supply-demand activities.

Between $\boldsymbol{i}$ and $\boldsymbol{j}$, there is an amount of cocoa being transported ($\boldsymbol{y}$) at time $\boldsymbol{t}$. In particular, the cocoa being transported is distinguished based on its quality level (bulk or premium). Thus, let $\boldsymbol{d}$ be the specific quality of cocoa being transported. As the supply-demand characteristic of a supply chain, there would be demand ($\boldsymbol{D}$) at $\boldsymbol{j}$ for specific cocoa quality $\boldsymbol{d}$ at time $\boldsymbol{t}$. The demand comes as a derivation of final demand at the export gathering point (Pidie Jaya) to immediate buyer of a cocoa-producing region. Because demand is an exogenous variable and uncertain, it is stated as a stochastic variable ($\boldsymbol{\omega}$) with the standard deviation of historical demand records as the basis of probability distribution. Next, production node has a cost ($\boldsymbol{C}$) or production ($\boldsymbol{Pr}$) at location i ($\boldsymbol{C_i^{Pr}}$). Besides, there is a cost ($\boldsymbol{C}$) of transportation ($\boldsymbol{Tr}$) between locations $\boldsymbol{i}$ and $\boldsymbol{j}$ ($\boldsymbol{C_{ij}^{Tr}}$). In terms of value chain, price ($\boldsymbol{P}$) is derived from final price at endpoint to local price between two trading partners $\boldsymbol{i}$ and $\boldsymbol{j}$ for specific cocoa quality $\boldsymbol{d}$ ($\boldsymbol{P_{ij}^{dt}}$). Because prices for different cocoa quality are different, so let $\boldsymbol{P_{ij}^{dtBs}}$ be the base price ($\boldsymbol{Bs}$) of standard cocoa quality. If there is no difference between price being set for a quality level to the quality being delivered, so applicable price is the same as the base price.

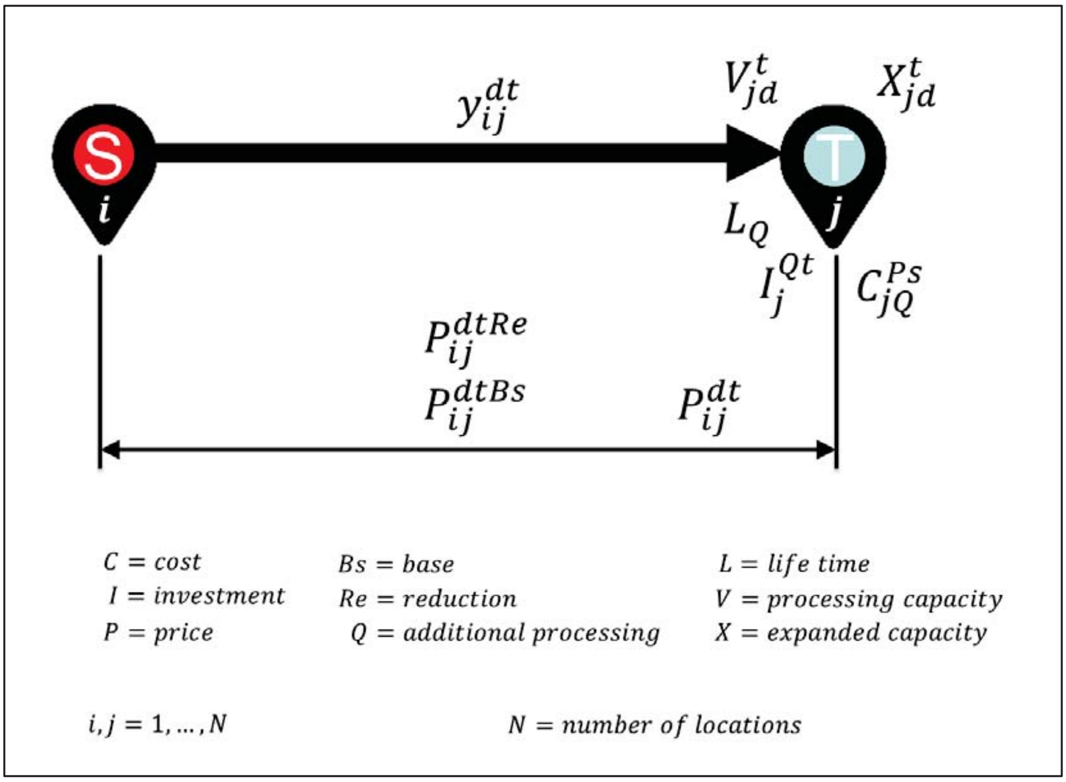


Figure V.13. Existing processing activities.

V.3.2 Processing activities

Furthermore, current processing activities must also be observed first (Figure V.13). If there is a need to do additional processing ($\boldsymbol{Q}$) at location $\boldsymbol{j}$, there would be a capacity of the added processing ($\boldsymbol{V}$). Because processing for different cocoa quality ($\boldsymbol{d}$) are different, so the processing is specific for each quality level in location $\boldsymbol{j}$ at time $\boldsymbol{t}$ ($\boldsymbol{V_{jd}^{t}}$). For each processing activity ($\boldsymbol{Ps}$), let $\boldsymbol{C_{jQ}^{Ps}}$ be the cost ($\boldsymbol{C}$) that applies specifically for a technology ($\boldsymbol{Q}$). For each technology taken to conduct the additional processing ($\boldsymbol{Q}$), there would be a limited lifetime ($\boldsymbol{L_{Q}}$). When there is a need to expand capacity ($\boldsymbol{X}$) for a specific cocoa quality ($\boldsymbol{d}$) and/or replace technologies that have reached their lifetime ($\boldsymbol{L_{Q}}$) at location $\boldsymbol{j}$, let $\boldsymbol{X_{jd}^{t}}$ be the expansion capacity of technology for additional processing of specific cocoa quality. Every time expansion occurs, there would be an investment ($\boldsymbol{I}$) required for a processing technology ($\boldsymbol{Q}$) at location $\boldsymbol{j}$ ($\boldsymbol{I_{j}^{Qt}}$). In terms of price variable ($\boldsymbol{P}$), current situation shows that there is in fact a price reduction for farmers due to the low quality of cocoa they offer to immediate buyers. Thus, price reduction ($\boldsymbol{P_{ij}^{dtRe}}$) acts as lowering factor for a specific quality of cacao ($\boldsymbol{d}$) transported from location $\boldsymbol{i}$ to $\boldsymbol{j}$ at time $\boldsymbol{t}$. The reduction allows base price ($\boldsymbol{P_{ij}^{dtBs}}$) to get reduced to produce applicable price ($\boldsymbol{P_{ij}^{dt}}$).

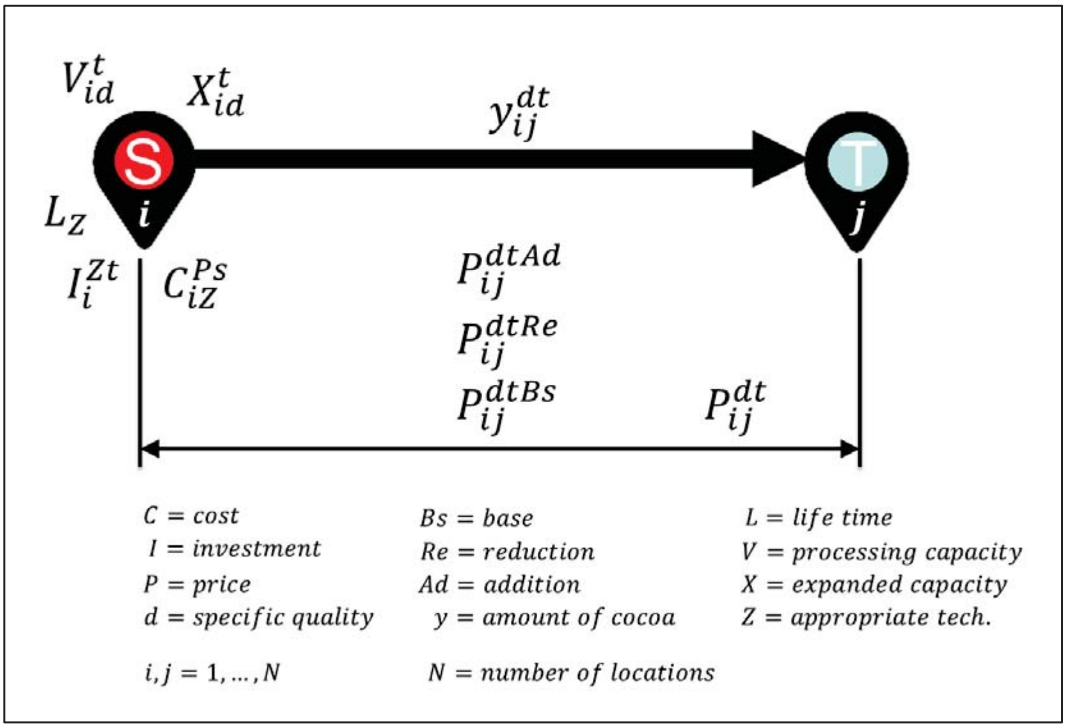


Figure V.14. Intervention processing activities.

When the local change (appropriate postharvest technology ($\boldsymbol{Z}$)) is introduced to the current system, there would be a shift of activities (Figure V.14). The most obvious one is the moving of postharvest processing (fermentation and drying) from distribution node ($\boldsymbol{j}$) to producing node ($\boldsymbol{i}$). The moving would also move attributes of processing embedded to the processing activity. Thus, let $\boldsymbol{V_{id}^{t}}$ be the processing capacity ($\boldsymbol{V}$) of appropriate postharvest technology being introduced to produce a specific cocoa quality ($\boldsymbol{d}$) in location $\boldsymbol{i}$ at time $\boldsymbol{t}$, while let $\boldsymbol{X_{id}^{t}}$ be the capacity expansion ($\boldsymbol{X}$) of appropriate postharvest technology in location $\boldsymbol{i}$ to replace broken technology and or expand totoal capacity to fulfill demand of a specific cocoa quality ($\boldsymbol{d}$) at time $\boldsymbol{t}$. Next, let $\boldsymbol{L_{Z}}$ be the limited lifetime ($\boldsymbol{L}$) of appropriate postharvest technology $\boldsymbol{Z}$. To do expansion or replacement, let $\boldsymbol{I_{i}^{Zt}}$ be the investment required for technology $\boldsymbol{Z}$ in location $\boldsymbol{i}$ at time $\boldsymbol{t}$. Then, let $\boldsymbol{C_{iZ}^{Ps}}$ be the cost ($\boldsymbol{C}$) of processing ($\boldsymbol{Ps}$) by appropriate postharvest technology ($\boldsymbol{Z}$) in location $\boldsymbol{i}$. Then, there would be an expected addition ($\boldsymbol{Ad}$) due to the improved quality after the use of appropriate postharvest technology ($\boldsymbol{Z}$). Thus, applicable price ($\boldsymbol{P_{ij}^{dt}}$) between location $\boldsymbol{i}$ and $\boldsymbol{j}$ for a specific cocoa quality ($\boldsymbol{d}$) at time $\boldsymbol{t}$ would be the result of base price ($\boldsymbol{P_{ij}^{dtBs}}$) reduced by price reduction ($\boldsymbol{P_{ij}^{dtRe}}$) and added by price addition ($\boldsymbol{P_{ij}^{dtAd}}$).

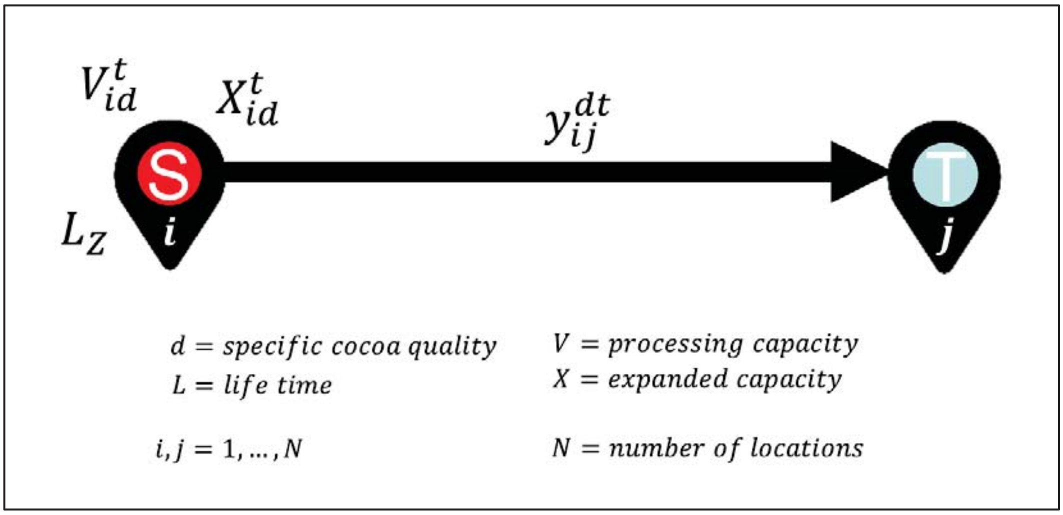


Figure V.15. Total production activities.

After all attributes of postharvest processing activities for new system are defined, total production for the news system can be declared (Figure V.15). As the first condition, assume that there is a processing capacity ($\boldsymbol{V}$) in location $\boldsymbol{i}$ for specific quality $\boldsymbol{d}$ at time $\boldsymbol{t}$.

$$\boldsymbol{V_{id}^{t} \geq 0}$$

The assumption declares that the system is in work, producing cocoa as it is. Thus, total processing capacity in location $\boldsymbol{i}$ at time $\boldsymbol{t}$ is expressed as

$$\boldsymbol{V_{id}^{t} = V_{id}^{t-1} + X_{id}^{t} - X_{id}^{t-L_z}}$$

where $\boldsymbol{V_{id}^{t-1}}$ indicates processing capacity at an immediate previous time, while $\boldsymbol{X_{id}^{t-L_Z}}$ is the capacity reduction due to a need of replacing appropriate postharvest technology ($\boldsymbol{Z}$) that has reached its lifetime ($\boldsymbol{L}$). In the beginning of introduction, let $\boldsymbol{V_{id}^{0}}$ as the intitial capacity.

Next, every supply chain flow may involve more than two levels of buyer or intermediary. By putting every flow as a single distributional pathway, let assume that in a supply flow there are four (4) sequential locations ($\boldsymbol{i, j, k, l}$) with the existence of appropriate postharvest technology ($\boldsymbol{Z}$) introduced at cocoa-producing node ($\boldsymbol{i}$). On the other hand, there are in fact variabilities occur all over a supply chain flow. First, there are variability of demand due to uncertain demand at endpoint, which is then derived to every supply chain path connected to the endpoint. From producers' side, yield also varies due to seasonal and uncertain climate condition. Due to the variability of demand and supply, price would also vary. Some other factors may also vary, but those three variables are ones with the most obvious variability; hence they are stated as being stochastic variables.

Since the existence of those variabilities, some constraints would also be occurring in their stochastic version. The first is demand constraint, by which the result of conversion yield due to the use of appropriate postharvest technology ($\boldsymbol{Z}$) with its conversion coefficient ($\boldsymbol{K}$) to final a quality type ($\boldsymbol{d}$) in location $\boldsymbol{i}$ at time $\boldsymbol{t}$, which is expressed as

$$\sum_{i} \boldsymbol{K}_{it}^{Zd}\, \boldsymbol{y}_{iZjkl}^{t}(\boldsymbol{\omega}) \geq \boldsymbol{D}^{dt}(\boldsymbol{\omega})$$

Besides, there will be an investment constraint to ensure that farmers can replicate or expand the appropriate postharvest technology being introduced ($\boldsymbol{Z}$) by themselves, meaning that the required investment ($\boldsymbol{I}$) for an expansion capacity ($\boldsymbol{X}$) must be lower than their investment capability. It is expressed as

$$\sum_{iZ} \boldsymbol{C}_{iZt}^{Ps}(\boldsymbol{\omega})\boldsymbol{X}_{id}^{t} \leq \boldsymbol{I}^{t}(\boldsymbol{\omega})$$

Besides, there would be a variability in terms of the total processing capacity of technologies being applied at time $\boldsymbol{t}$. Thus, there is a need to define the total coverage of the total capacity to the required capacity to cover all cocoa to achieve a premium level. The coverage is defined as the availability factor ($\boldsymbol{G}$) in location $\boldsymbol{i}$ to produce specific quality $\boldsymbol{d}$ at time $\boldsymbol{t}$. Because there is a need to maintain the availability factor at maximum coverage yet minimum cost and investment, $\boldsymbol{0} \leq \boldsymbol{G}_{i}^{t}(\boldsymbol{d}) \leq \boldsymbol{1}$ is interpreted as an availability factor for $\boldsymbol{X}_{id}^{t}$. Thus, the number of expansion in location $\boldsymbol{i}$ at time $\boldsymbol{t}$ to fulfill demand $\boldsymbol{D}^{dt}$, which is expressed as

$$\boldsymbol{y}_{iZjkl}^{t}(\boldsymbol{\omega}) \leq \boldsymbol{G}_{i}^{t}(\boldsymbol{d})\boldsymbol{V}_{iZjkl}^{t}$$

Then, as an optimization stage, there would be different optimized situation for different supply chain members. Farmers, as the least developing party, may prefer to focus on minimize cost first. However, intermediaries prefer to have maximized profit as the goal function. Then, the supply chain as a whole aims at maximizing supply of high-quality cocoa to fulfill demand. As this research aims at empowering farmers by increasing their bargaining position, the goal function of farmers becomes the primary optimization, while others' goal functions are taken as balancing functions to make sense of the whole situation throughout the supply chain by offering a consensus over time. The consensus dynamics mimics any real situation in which changes to a new system occur gradually by acknowledging different interests of different supply chain members over time.

$$\min_{t} E\left(\sum_{i,Z,j,k,l,t}\left[C^{Pr}_{iZjklt}y^{t}_{iZjkl}(\omega)\right]+\sum_{i,Z,j,k,l,t}\left[C^{Ps}_{iZt}(\omega)X^{t}_{id}\right]\right)$$

V.3.3 Market Structure

After proposing the general relations of producer and buyer in terms of processing activities, including any flow and exchange occurring between them, it is important to understand a higher level of the relations in the form of market structure (Boehlje, 1999; Reardon & Timmer, 2007; Renting *et al.*, 2003). In particular, understanding market structure is important in investigating the changing behavior of a system due to the natural change of market structure within a multi-agent dynamics setting. As a concept, the structure of a market refers to the number and characteristics of participating actors in the market at a specific supply chain level. Practically, the structure of a given market is possible to take the form of either concentrated or unconcentrated one. Besides, the structure of a market is stated as tightly affecting the conduct (behavior) and performance of participating actors in the given market. As a matter of facts, a unique feature of the markets of a primary commodity is the considerably larger number of producers relative to buying actors. The situation has made most markets of many primary commodities to take the structural form of an oligopsony market (Just & Chern, 1980; Rogers & Sexton, 1994).

In a general understanding, oligopsony conceptually refers to a given market that is dominated by a numerous number of sellers who conduct trading with only a quite fewer number of buyers. Looking at the unbalanced situation, it is considerably yet another form of an imperfect competition, in which it takes a contrast situation compared to an oligopoly market that has a fewer number of sellers and a numerous number of buyers. In the world's cocoa industry, the market is generally stated as being concentrated when it consists of just a quite fewer buyers than cocoa producers, or unconcentrated when it consists of considerably more buyers than producers. In a national or local market, the internal market for dried cocoa beans is consisted of a number of middlemen who are engaged in a competition with each other to gain a piece of market share. As aforementioned earlier, a middleman may appear as either a non-producing (processing) buyer or another producing actor (farmer) who acts as an intermediating actor in-between a higher-level buyer and producers (or other producer-buyers) who are located in another location that include a transportation path involving the location of the middleman.

Chapter VI MODEL TESTING
Results and Discussions

VI.1 Intervened supply chain stage: Cocoa drying process

Based on previous explanations, cocoa post-harvest processing becomes the targeted process. Practically, Amin (2009) has explained that the process consists of four primary activities. It begins since cocoa fruits are harvested from the trees until the beans are transformed to be ready-to-sell ones (Figure VI.1). The first activity is the fruit splitting. After the fruits are harvested from cocoa trees, each of them must be splitted to harvest the beans. The splitting activity is conducted by using fruit dull-blade to avoid the destruction over contained beans. Cocoa fruits are splitted in crosswise direction to its longitudinal. The purpose is to ensure clean beans harvesting and produce shorter fruit peels. Then, the beans are harvested. The harvested ones are the wet beans that is still covered by white pulps, so pulp removal must be done. Besides, unremoved pulps will become garbages when the beans are dried, which means that it will add additional price reduction for farmers. Usually, the pupls are removed manually by hand. Another cleaning technique also allow pulp-covered beans to be washed for skinning the pupls, yet such technique seems dangerous to the quality of cocoa beans and also increase their water moistures.

Then, after the beans are cleaned, they are fermented to decrease the sugar substance naturally contained in wet cocoa beans due to long interaction with pulps inside cocoa fruits. Such process also transform sugar substance to other ones which produce stronger cocoa taste and aroma (Ülrich, 2009). Fermentation is conducted by maintaining natural condition of wet beans in an isolated chamber/container. Fermentation as a natural phenomenon will be automatically happened since the wet beans are not disturbed for certain period. Fermentation is usually done in some iterations to ensure uniform distribution of chemical reaction by remixing wet beans every day. Fermentation process is not an optional phase and could be stated as a must, yet it has not widely applied in many developing communities since it is a known intervention from a considerably more advanced scientific knowledge. Then, the beans – whether they are fermented or not – are dried to produce dry cocoa beans. Drying process is conducted by vaporizing water in the beans to decrease water moisture percentage until a demanded level. Drying process can be done by using any techniques as long as such techniques produce drying phenomena to the dried beans. Drying process is the last activity of cocoa post-harvest processing since the dried beans will next be processed into many secondary products depend on the producers.

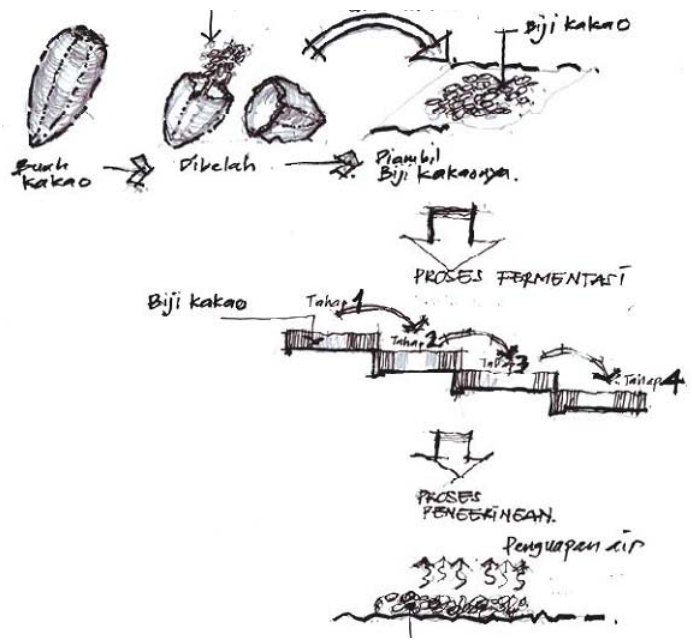


Figure VI.1. Cocoa post-harvest processing steps (Amin, 2009).

Throughout those four activities, there are weight decreases happened to cocoa beans. Weight decreases are the results of three activities: de-pulping, fermentation, and drying processes. Table VI.1 shows the differences between weight decreases affected by three possible conditions in post-harvest processing. Cocoa beans without de-pulping and fermentation processes can be dried and produce about 36% for its original weight to get around 7% water moisture. Original weight is one which is happened just after the beans are harvested from the fruits. This condition means that the beans will loose around 64% of their weight in drying process. The second possibility is fermentation + drying processes. Such condition will produce 54% mass reduction until the beans reach 7% demanded water moisture after dried. Fermentation process itself will produce about 10% mass decrease from beans' original weight. Then, the most complete possibility is the second one plus de-pulping acitivity before fermentation. De-pulping activity will decrease the mass by 20% from original wieght. Besides, fermentation will further remove about 8% from original weight. Drying process reduces 36% mass to produce 36% rendement calculated from original weight in order to get 7% water moisture. In short, each of those activities reduce mass of cocoa beans in different influences, yet the final result is remain same due to demanded water moisture percentage. The best option is the most complete one. It will produce suitable water moisture with demanded level, less sugar substance, better taste & aroma, and less garbage.

Table VI.1. Drying yield of cocoa beans

	De-pulping and fermentation	*Fermentation only*	*No processing before drying*
Fresh cocoa beans	**1,000 kg**	**1,000 kg**	**1,000 kg**
After *de-pulping* process	800 kg	-	-
After *fermentation* process	**720 kg**	**900 kg**	
Dry beans (after drying process – water content 7%)	360 kg	360 kg	360 kg
Mass reduction in drying process	360 kg	540 kg	640 kg
Mass reduction resulted by drying process to the mass of fresh beans (yield)	36%	54%	64%

**source: Ulrich (2009)*

VI.2 Technological solutions being introduced

VI.2.1 Current difficulties for technological solutions

On fields, world's smallholder farmers were responsible for roughly 70% of total global cocoa production (Clay, 2004; Donald, 2004). An estimated 5-6 million smallholder farmers all around the world earned most or all of their cash income from cocoa production (Clay, 2004). However, when small-scale farmers in Aceh sell their dry beans to next level buyers, they receive a low cash income from the buyers. Their low payment is particularly caused by a referrence on a reduced standard price by the percentage of exceeding water moisture, garbage, and flat beans found among dried beans. It means that a large portion of exported cocoa dry beans from Aceh have a low quality compared to market requirement. A condition as such is critically caused by a low attention to cocoa post-harvest processing. As aforementioned, the processing consists of two critical stages, *i.e.* fermentation and drying process. In fact, these steps determin the final quality of dry cocoa beans. While fermentation is taken to create taste and aroma, drying process is required to decrease water moisture in wet cocoa beans to a demanded percentage in the market, which is usually set at between 7%-8% (Ülrich, 2009).

Unlike the downstream processing steps in the Northern hemisphere, the upstream processing steps in Southern hemisphere, including Aceh – Indonesia, rarely involve sophisticated equipments (Ng, 2011). In particular, small-scale farmers in Aceh are experiencing many difficulties to access technological solutions that may support them to produce better dried cocoa beans (Ulrich, 2009). It is in fact different to smallholder farmers in other cocoa producing regions in Indonesia, including those in Eastern Sulawesi and Java. In their current practice, farmers in Aceh is using a traditional method to dry cocoa beans by drying the beans in a flattened plastic sheet openly under the sun. The method has caused mixed garbages among dried beans, which then results in a decrease in selling prices. Because flat beans are primarily caused by on-farm cultivation method, drying process must be optimized to overcome such problems. As a matter of facts, most farmers in Aceh have not applied a good fermentation technique or are using no fermentation at all for wet cocoa beans. Few others have done it, but by implementing a very traditional way by keeping wet beans inside a gunny for several days. Therefore, technological solution to be introduced in postharvest processing holds a critical position to optimize the final quality of ready-to-sell dried cocoa beans and delivers higher values and benefits for smallholder farmers in Aceh, Indonesia.

VI.2.2 Present intervention: First technological change

As aforementioned, the intervention to introduce into the cocoa supply chain in Aceh, Indonesia, needs to take a form of a postharvest processing equipment. In particular, the technological solution being introduced is intended to intervene cocoa drying process as a widely-applied yet ineffective postharvest activity in its current practice. As indicated in literature review (Figure II.8), technological change for vulnerability eradication in a vulnerable community is suggested to have a continuous progress from micro to macro changes. In that manner, technological solution being introduced into the model consists of two different technologies in two distant time of application, *i.e.* present and future interventions. While the time and performance may differ, however, both are intended to intervene the same postharvest activity, *i.e.* drying process.

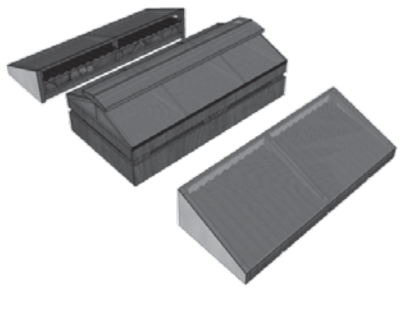


Figure VI.2. Present technological intervention.

The present technological solution is an existing cocoa dryer taken from another cocoa producing region. In this case, it is particularly treated as a given technology transferred from a foreign region outside Aceh, Indonesia. The cocoa dryer is so-called “Afiluo” (Sianipar & Widaretna, 2012), which is taken from Nias, Indonesia, a remote island with a considerably near distance to Aceh. The appropriate technology takes a form of modular design (Figure VI.2), with a scalable capacity. The technical specifications are as follow. The technology can dry 12.5 Kg of wet cocoa beans per meter square. Because one set of dryer has 2x1 m size, the total capacity for one drying cycle is 25 Kg. In doing drying process, the technology utilizes natural light from the sun, in which the whole drying cycle is expected to take about 2-3 days to finish. Besides, the yield of drying process using the technology is expected to produce a 6.8% mater moisture, which is just below 7%-8% market standard. Then, the technology has a 3-year lifetime. Speaking the economic specification, the technology requires Rp1,007,375 investment for materials and Rp360,000 for construction workforce. Considering value added gained in the form of a higher price (payment) received by farmers due to the premium quality of dried cocoa beans, the investment, particularly materials, is expected to reach a return-on-investment after about 4 months of usage.

VI.2.3 Future intervention: Second technological change

The second technological solution is posited as a possible future technological change occurring in are under observation. In general, a second technology needs to be stated as a product of internal development within local communities. Yet, the technology development process is currently excluded from the model to establish a fully quantifiable boundary with less bias between sub-regions. Thus, technology being introduced in the future for this case takes a form of another existing appropriate technology. In particular, an alternative drying equipment of “Afiluo” in Nias is taken as the second technological change. At first, it was developed as a form of model testing for DMAT (Sianipar *et al.*, 2013c). Technically speaking, it is not modular (Figure VI.3), yet it offers considerably better technical performance. Basically, one cycle drying may cover 25 Kg for a 2x1 m drying matress. However, the alternative technology requires a consistent 2 days for one cycle of drying. Thus, it can dry up to 30 Kg wet cocoa beans to catch up with 2-3 days drying time of the first technology. In fact, the bigger size is followed by a consistent drying yield to reach 6.5% water moisture, which is well below market standard and has a better potential to maintain the moisture level through a long supply chain. Next, the technology has a 3-year lifetime, which is the same as the first technology. In terms of economic investment, the second technological intervention is expected to require Rp1,631,350 for materials and the same Rp360,000 for construction labor. Hence, it requires Rp2,139,611 for a single set of dryer. Then, assuming that value added remains the same after years until the introduction of the second technology, return on investment for the future technological change is expected to occur after 6 months of usage for every set of dryer independently.

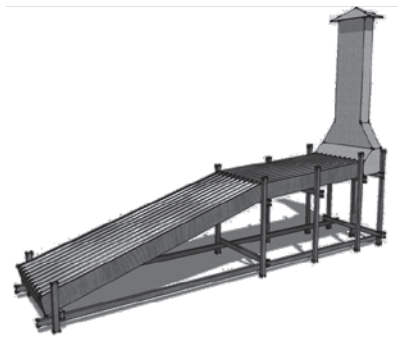


Figure VI.3. Future technological intervention.

VI.3 Multi-agent dynamics: The results

VI.3.1 Aggregated processing activities

By considering interconnected flows in the cocoa supply chain in Aceh, Indonesia, different supply chain members with different attributes as well as goal functions, and the shifts of attributes due to the introduction of appropriate postharvest technology, the result shows that the amount of cocoa beans being processed by farmers increase significantly yet dynamically change over time (Figure VI.4). The processed cacao refers to those fermented and dried, thus stated as being hig quality and got a premium price. The amount of cocoa being processed by farmers also indicate the size of need of the existence of intermediaries, meaning that the more farmers are able to process more cocoa beans by themselves, there is less need of having unnecessary intermediaries as their trading partners.

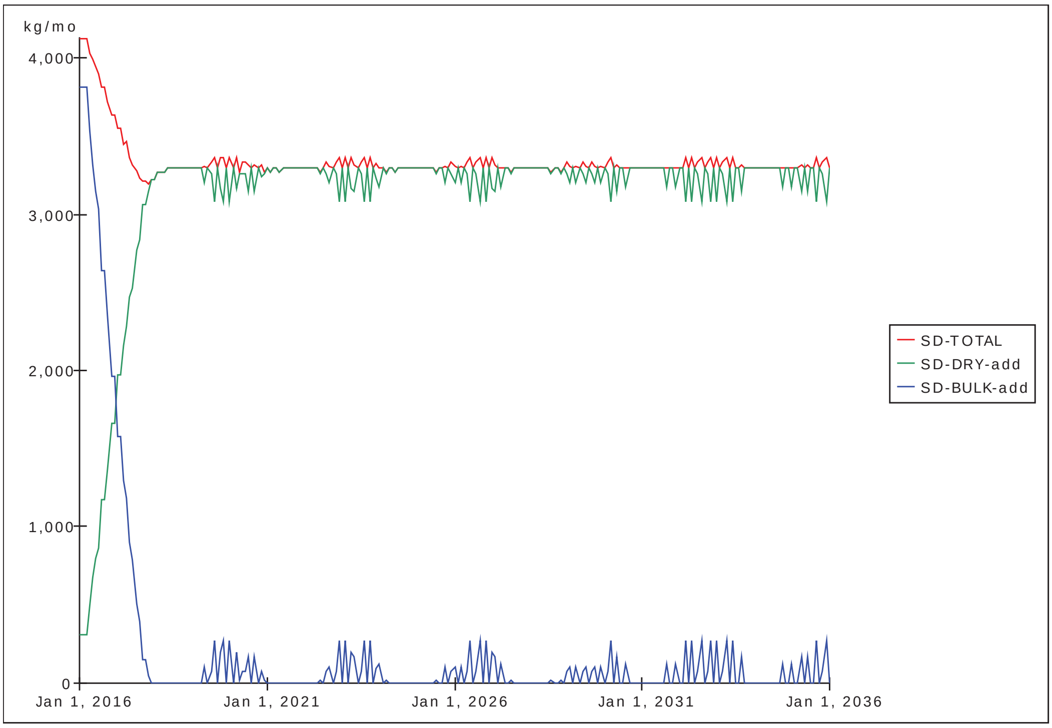


Figure VI.4. Processed cocoa beans over time.

In other words, the need of intermediaries gets nulled if farmers are able to process the whole amount of cocoa they produce themselves, because they do not need anyone to do additional processing anymore. From the results (Figure VI.4), the need of having intermediaries within the new system being pushed would get nulled in less than five years, meaning that the new system would simplify itself and produce a more efficient supply-demand flows after the time. However, chances exist for intermediaries to come back into the system, as the coverage of appropriate postharvest technology being introduced and replicated may get reduced at some points. It is caused by the lifetime of each technology to reach replacement period, in which during the replacement intermediaries may take their chance to get additional income by doing required additional processing again.

Besides, it it is very interesting to see that the dynamics of availability factor of the appropriate postharvest technology being introduced occur in different pattern at different period indicating that there is different behavior of replacement due to different accumulated savings, required expansion capacity, *etc.*, by each farmer at a discrete time $\boldsymbol{t}$. It also indicates the pattern of past-dependencies, which states that the behavior of the fluctiation of availability factor at one discrete time $\boldsymbol{t}$ is affected by past fluctuation behavior that had been affected by its own previous fluctuation behavior. The result shows very different patterns of availability factor patterns due to the complexity of different behavior between farmers, intermediaries, supply chain flows and all other variabilities.

VI.3.2 Aggregated number of technologies

In terms of the aggregated number of appropriate postharvest technology being introduced, the dynamics also occur over time (Figure VI.5). In the beginning, the number increases consistently due to the increasing investment capability of farmers as the result of selling better cocoa quality. In less than 5 years, the number reaches a stationary, indicating the maximum coverage of total capacity of these technologies to required capacity demanded by bulk cocoa being produced. After some technologies reach their lifetime, the number fluctuate again because some technologies broke and need replacement. After the coverage comeback, the number of technologies would be stationary again. Parallel to dynamic behavior of processing activity (Figure VI.4), the number of technologies being applied fluctuate with different patterns during different replacement periods. It is caused by the time required to replace every single technology, in conjunction with the varied need of having an expanding capacity and availability of savings to replace the technology. Thus, the pattern also shows past dependencies because future behavior is affected by current behavior that has been affected by past behavior.

Furthermore, there is an additional event introduced into the new system in the future (Figure VI.5; Introduction). It is expected that at the 10^{th} year, another appropriate postharvest technology will be introduced into the system. The new technology is expected to have a better performance. It is introduced as an exogenous event, meaning that the development of the new future technology will not occur within the system. The new future technology is expected to be another shift of the new system into another newer system in the future. The future introduction would be the driver of those, repeating current effort with different attributes and effects.

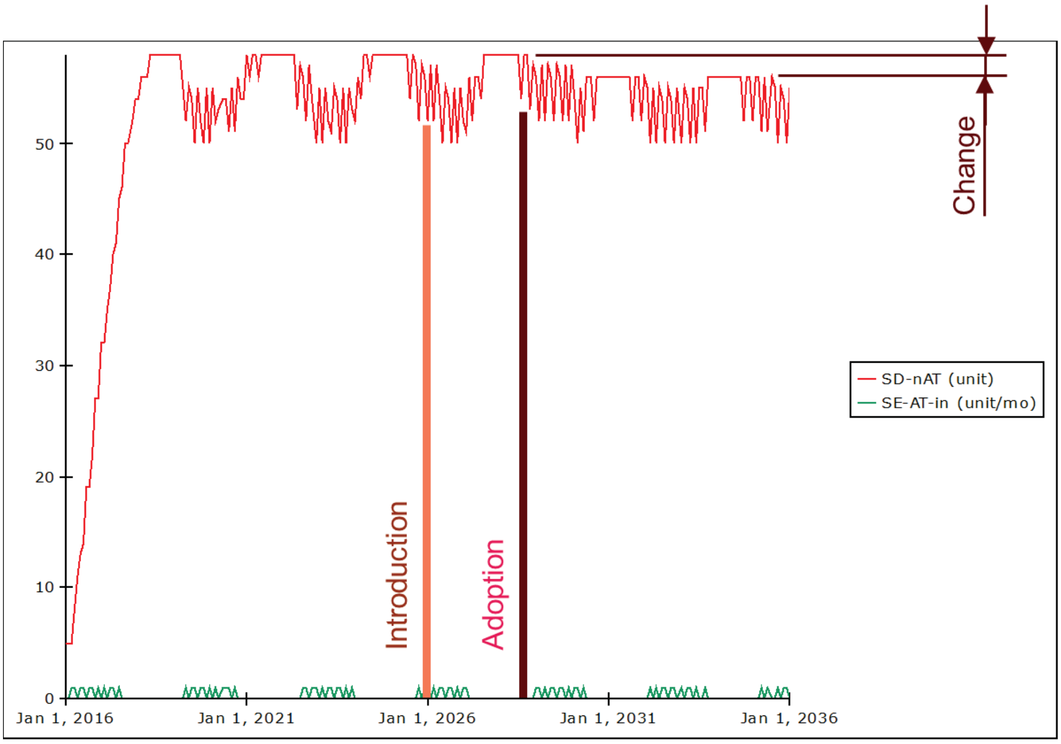


Figure VI.5. Aggregated number of technologies (new & future).

The result (Figure VI.5) is hence distinguished by observing the first ten years and the second one. The first 10-year is the period of having first appropriate postharvest technology introducted in the current situation. The second 10-year period will witness the availability of a new appropriate technology with the same function as the current one but with better technical and economic performance. The result appears to show that even if the new technology is introduced in the 10^{th} year, it will not be adopted by farmers until after four or five years after that. It can be seen by looking at the maximum number of technologies being applied at stationary after the introduction. The stationary level is still the same as before, indicating that farmers will still use currently introduced appropriate technology even if they see a better technology during the replacement period circa the 10th year. The adoption will occur since the next replacement period after one around the introduction year. It can be seen by looking at the change of stationary condition. While stationary level indicates the maximum coverage of total technologies being to required processing capacity, the change of stationary indicates that the number of technologies being applied still covers all cocoa being produced. Because the new future technology is expected to have better performance, so the number of technologies at full processing coverage (stationary level) will be lower than the currently introduced technology. Then, the new future technology will also have fluctuating number due to its replacement period, in which we can see quite different fluctuation behavior compared to those of the currently introduced technology. The application of the new future technology has stronger response to conduct the replacement of every single broken technology, showing a promising evidence of having a lower chance to intermediaries to comeback to the system.

VI.3.3 Savings: An aggregated fragment of incomes

Then, the last observation is conducted to the savings dynamics of farmers. In a general situation, a farmer defines savings as a fragment of one's incomes. The fragment is accumulated over time to produce savings after some time. Thus, aggregated savings of all farmers in the new system indicate their savings behavior affected by dynamic situation in the system over time. Looking at the result (Figure VI.6), savings behavior of all farmers consistently increase with disruptions during every replacement period of technologies being applied. In the beginning, farmers struggle to accumulate savings because they need to replicate appropriate post harvest technology being introduced to cover all required capacity. After maximum availability factor has been reacher, they begin to have significant increases of savings. During a replacement period, their savings will decrease. The interesting point is to see the behavior of the drecrease as being different over time. In particular, the decrease becomes slower over time, producing less decreases in following decreasing period. It shows that the application of appropriate postharvest technology can produce a persistent savings over time. Besides, it is also interesting to see that the persistency of savings to disruptions will increase after the adoption of new future appropioate postharvest technology. The new technology will significantly strengthen farmers' savings despite the need to reinvest for replacing technologies again. After about 25 years, farmers' savings will have a very strong persistency against disruption by looking at the horizontal trend of the savings disruption. After that, the savings keep increasing even though farmers need to reinvest their savings to conduct another replacement period.

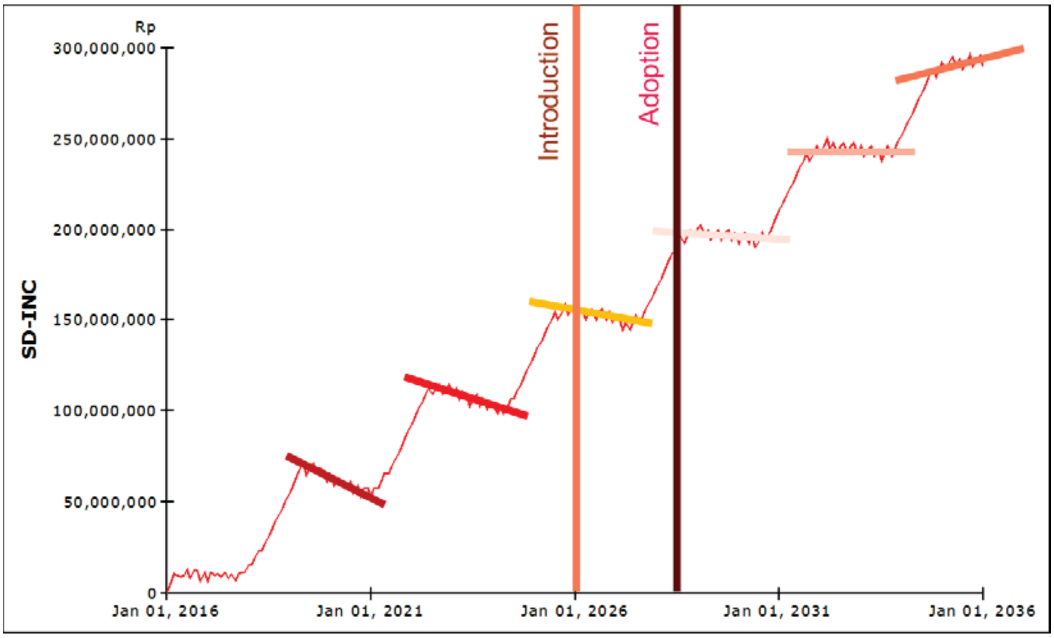


Figure VI.6. Changes in savings over time (new & future technologies).

Chapter VII CONCLUSIONS
Summary, Limitations and Contributions

VII.1 Summary and conclusions

The cocoa industry in Indonesia has been recognized as being one of the biggest cocoa producer, yet it has many vulnerabilities. First, it lacks technological accesses. Farmers in Indonesia still use conventional technology to do postharvest processing, and they hence produce low quality cocoa beans for being sold to their immediate buyers. The low quality later produces a very low price paid by immediate buyers for cacao they got from farmers. To get a better price, intermediaries conduct further processing over those bulk cocoa, gaining more margin from low price they pay to farmers. As the result, economic inequality is widening, making farmers to get lowest economic rewards for their own products. Next, cocoa industry in Indonesia has a low environmental awareness, because in fact there is no standardized environmental index for cocoa in the world. They hence feel no urgent need to conduct environmental-friendly activities. Then, economic inequality and technical difficulty to produce high-quality cocoa beans have triggered a weak social justice. Farmers become the least developing party with the lowest bargaining power. They thus have a less chance to change their situation and achieve a better prosperity.

VII.1.1 Answering research questions 1 & 2

The way to change the situation appears to exist by using empowerment as the mindset of development for the industry. Empowerment paradigm ensures that any effort to develop a least developing party (in this case: farmers) has an intention to maintain their development by themselves, making them able to survive with less dependencies to outside counterparts. In terms of coca industry, it is useful to reduce the depencency of farmers to all other supply chain members. Thus, it is expected that farmers can produce better product, gain more economic benefits and do more efficient technical works by being empowered. In that sense, appropriate technology is found to be a promising technological change to conduct the empowerment, because it offers a good technical performance with maximum economic benefits possible at low environmental impacts.

VII.1.2 Answering research question 3

Next, a combination of appropriate technology and postharvest engineering triggers the need of having systems analysis over the whole cocoa supply chain in the region under observation. The systemic impacts of the appropriate postharvest technology being introduced is analyzed by investigating the dynamic of processing activities, number of technologies being applied, and savings accumulated by farmers due to the use of the technology. In particular, processing activities are observed by looking at the coverage of total processing capacity of the technology to total required processing capacity due to the amount of bulk cocoa being produced. The observation is designed to reveal maximum number of technology required to process all bulk cocoa and to see the reduced need of having intermediaries to conduct additional processing. The reduced needs indicate a more empowered state of farmers to survive by themselves.

Acting as a local change, the introduction of the appropriate postharvest technology triggers systemic impacts to the whole cocoa industry in Aceh, Indonesia. First, it shows that the need of intermediaries is nulled is less than five years. However, the need comes back when the availability factor of technology cannot cope with total production. Besides, the increase of savings is more persistent over time, especially after the nulled need of intermediaries. Furthermore, new future technology being introduced in the 10^{th} year is expected to get adopted in 4-5 years afterwards. Its adoption also shows lower total number of technologies being applied while still maintaining maximum availability factor. Then, the new technology produces more persistent increases of savings.

VII.2 Original contributions

Then, this research has been offering some original contributions to related bodies of knowledge. First, this study gives a notion in which a shift in thinking from a typical development paradigm in current development engineering theory regarding the provision of technological solutions could have a significant impact on vulnerable communities, including their vulnerability eradication efforts, and their successful survivable development. Besides, the current research proposes insights to move scientific progress toward a more holistic vulnerability eradication using appropriate technology as a technological solution both in conceptual and practical levels. Theoretically-speaking, systems analysis is extensively used in this research with an arguable leap to integrate system dynamics, agent-based modeling and discrete event simulation in a single analysis in the form of a intermodel approach. Thus, the research offers an extended construct of each of these matured methods, while also initiate a critical example of using more than one modeling approaches that philosophically have different epistemological and ontological characteristics and attributes. Then, the study shows a practical example of the intermodel approach, delivering a notion in which it is possible to apply into a real case without any significant scientific barrier.

In general, the multi-agent dynamics being introduced adds a capability of using a flexible system structure compared to the nature of system dynamics. In a typical system dynamics, the dynamics refers to the behavior of the result of a system, in which the structure of an observed system is assumed to be matured (fixed). In a multi-agent dynamics setting, the structure of an observed system follows the change of needs of different agents at the interaction of two or more pools of different types of agents. Practically, system dynamics focuses on the interactions of influencing factors within a system context, while multi-agent dynamics focuses on the interactions of agents that later affects different sets of attributes over time.

In a multi-agent dynamics, any interaction between influencing factors is therefore stated as being fluid, indicating a flexible operational scheme occurred within the system at a different measurement period. The dynamics in a multi-agent dynamics takes the form of a dynamic dynamics, imposing different patterns of behavior over time in comparison to a more-likely stable cyclical dynamics produced by system dynamics modeling. On the other hand, system dynamics has a limitation in modeling a multi-agent context. A system dynamics model requires a set of model extension for every agent introduced into the model. In that sense, multi-agent dynamics offers a simpler modeling by applying the perspective of agent pool consisting of a particular type of agents for a specific structural level.

Compared to agent-based modeling in particular, the multi-agent dynamics perspective being introduced offers a capability of defining a clear structure of an observed system. In an agent-based modeling setting, an observed system is stated as having a fully fluid structure, or pratically no clear structure. The particular characteristic of agent-based is caused by the focus of the modeling on potential interactions between individual agents instead of possible interactions between different sub-structures in a system being investigated. In other words, there is only one fully-fluid pool of agents, in which each agent has a set of attributes that may have different value as the result of interactions being modeled. As the result, agent-based modeling does not necessarily offer a capability of modeling the existing structure of an observed system, hence limiting its possibility to investigate structural dynamics. In a multi-agent dynamics setting, a system is treated as well-structured yet flexible, making it able to establish the model of an observed system that has a known structure while at the same time offering a possibility of changing structure due to the interactions between agents. The capability being offered is resulted from the focus of multi-agent dynamics on interactions between agents from different pools. In a multi-agent dynamics setting, an interaction is primarily stated to occur between two or more pools of agents, in which each pool consists of only one type of agents. In addition, one type of agents may have two or more pools as the consequence of system structure. Despite having a possibility to also model interactions between agents in their specific pool, the flexible division of pools shapes a form of layered structure between pools. For example, a pool of a specific agent type may interact with another pool consisting of another agent type, which later interacts with another pool of agents with the same type of the first pool. The layers may also change if a pool of agents needs to interact with a parallel pool with another agent type. In short, the layered and flexible interactions are the structure of an adaptive system. Therefore, multi-agent dynamics adds an important capability by-nature over agent-based modeling.

Then, the multi-agent dynamics being proposed adds a capability to a typical discrete-event simulation. In particular, multi-agent dynamics offers a capability of observing the effect of discrete choice in a delayed or fastened manner following any required state that has to achieve a particular level to apply the choice or to introduce desired effects of the choice. In a discrete-event simulation, choices are stated as primarily having two distinct options, meaning that a changing behavior occurs if and only if the choice shifts from one option to another. As a consequence, a different set of processes or attributes is activated by the shift, imposing different system behavior in any following simulation stage. In a multi-agent dynamics setting, on the other hand, a discrete event is posited as an intervening force. Practically, an intervention may take the form of either an additional system sub-structure or a new governing policy. If an additional sub-system is introduced, the whole structure of an observed system would adapt to include the new layer of interactions. Meanwhile, the introduction of a new governing policy does not introduce a new sub-system, yet it changes the behavioral interactions between pools of agents or between agents in a pool. Thus, an intervening force acts as a discrete event with fastened or delayed effects to the whole existing system, in which staged flows of effects are more likely occurred due to the layered yet flexible system structure. In short, multi-agent dynamics contributes a significant capability to a typical discrete-event simulation.

VII.3 The potential for new applications

Looking at the characteristics of multi-agent dynamics being proposed, the potential for new applications in different types of system surely rises as a constructive concern. In general, the multi-agent dynamics offers a set of intermodel characteristics, including a capability to model the flexible structure of an observed system, layered interactions between either agents or pools of agents, and time-based as well as staged effects of a discrete intervening force, *etc*. At a conceptual level, therefore, the multi-agent dynamics surely fits the modeling of an observed system that has the following characteristics. First, it is appropriate to apply multi-agent dynamics if an observed system requires a flexible structure, *e.g.* a flexibility required within a trading system in which a buyer freely choose different seller, *vice versa*. Second, multi-agent dynamics perspective is applicable if an observed system requires fluid interactions between different groups of actors, *e.g.* interactions between societal groups in which every person interacts with others in one's group while one's group interacts with another group of people who have different interests. Third, an observed system is possible to investigate by being modeled according to multi-agent dynamics modeling if the modeling aims at discovering the success of an intervening force, *e.g.* new technology, new policy, new access to another system, new participating type of agents, *etc*., which considers any staged and delayed/fastened effect of the intervention to affect all structural layers within the observed system.

Chapter VIII RESEARCH INSIGHTS

VIII.1 General limitations and insights

On the other hand, several limitations also arise during this research. As a matter of facts, research limitations may also indicate opportunities for researchers in the future, whether in the form of an extension for the current research or a fully-separated one that is built from ground-up. The first limitation relates to the fact in which there is no existing environmental index for cocoa production in conjunction with the application of conventional and/or appropriate technology. Basically, it is possible to calculate the amount of environmental impacts being produced per mass of dried cocoa beans. However, the result may merely be a number without any distinguished meaning. In other words, it is quite impossible yet to see a better, or "greener" in a casual way of saying, condition if there are no existing record of environmental index for cocoa postharvest processes and related activities. Therefore, a further research is required to establish a set of environmental indices, providing a basis of environmental assessment on cocoa production, including its on-farm activities, postharvest processing and transportation. The research may take the basis of life-cycle assessment by considering some extended focuses on the effect to human health and the society at large. A research as such may deliver a distinguished contribution to the bodies of knowledge of both life-cycle assessment and cocoa research. It would also be a pioneering work on the impact of appropriate technology application on the environmental index of cocoa production.

Furthermore, this research assumes that technology development occurs as an exogenous process, meaning that any technology being introduced is merely given. Thus, it suggests a circumstance in which farmers cannot start a new-technology development by themselves. Empowerment paradigm being intended, however, requires a resonance between immanent and intentional developments, which is a situation wherein local people are posited to have a learning process that may later lead to the development of a new technology. The resonance gets along with numerous potential capacity building processes in a longer observation term, which would surely occur as the result of learning and knowledge processes within an observed vulnerable community. As a learning, the process is expected to act as a capacirty building for locals by which they are expected to conduct their own technology development in the future. The currently-applied exogenous technology development is hence becoming an obvious research limitation. To overcome a limitation as such, a further research is required to cover potential dynamics due ti the changes in capacity building of local people. In fact, a longer observation term, *e.g.* 20 years in this research, provides a good timeframe to conduct the wider coverage of modeling. However, a further research as such surely requires a team of researchers with a wider spectrum of expertise to include those with knowledge management, psychosocial, learning human institution, *etc*.

Then, within the modeling being proposed, there is currently no consideration of having economic crises or natural hazard occurring in an observed system, including their impacts to the application of an appropriate technology. In an actual situation, an economic crisis and/or environmental hazard are more likely to occur in a vulnerable community due to their fragile exposure to crises as such. Besides, a crisis would surely impact the application of an appropriate technology despite the inclusion of proper technological appropriateness in a technological solution. The impacts are particularly potential to occur on the systemic impact of a technological solution, which is the focus of the current research. Thus, the fact in which crises have not been included as a consideration during model building is another limitation of this research. The limitation may have triggered a need to conduct researches in the future that cover resilience issues as such. Resilience is in fact the ultimate goal of vulnerability eradication, meaning that the coverage on crises is the first step toward a resilient community/society. Another further research may also include risk analysis to resolve the issue of uncertainties. In the current study, uncertainties occur as if they occurred at the past, meaning that they are uncertain yet with certain historical patterns. Besides, pre-harvest trading contract may follow the potential of risk analysis, as farmers may get a more certain future due to the implementation of a pre-harvest contract, including strategic negotiation between the government and participating companies in a cocoa supply chain. Risk analysis over the pre-harvest contract and its impact on maximizing values for improving the prosperity of farmers may contribute significantly to the resilience of local people and the society at large.

VIII.2 Critical opportunity: Direct information system for market price

Commodities are traded all over the world. Limitations encountered by countries in fulfilling their national needs of commodities for consumptions have made supplies and demands to get ever-growingly exchanged between countries. In fact, any type of commodities is traded across countries, which may then depend on what kinds of products are required by a destination country. On that manner, market prices continuously change over time. In general, an excessively-long value chain has been occurring to almost all types of commodity, which has then weakened social justice for its members (Riley, 2008). As the weakest value chain member (Catalano, 2006), producers may not understand the origin of prices given for their products. Thus, a system is required to include all information in the chain for justifying a given market price for producers (Laib and Radjef, 2011). Besides, it needs to combine hardware and software to build a functional yet flexible structure. Thus, a question arises on what kind of system to deliver a justified market price for producers by processing a huge amount of information in a set of interconnected value chains. Besides, a critical concern to rises regarding required infrastructures to develop and the system and ensure its proper function.

VIII.2.1 Potential system framework

Social justice for communities as the producers of commodities being traded has been known as a critical factor to achieve a global resilience (Bailie, 2006; Sianipar and Widaretna, 2012; Sianipar *et al.*, 2013a). Any decision making on commodity price hence requires an adaptation to include all involved parties. In particular, value chain is becoming quite important in understanding price transformations from international markets to local trading activities. As a means for providing an agile and transparent value chain, information system is critically required. Engineers shall begin to include all activities at all trading levels within a value chain into price derivative equations. However, unique situations in each production area may trigger obstacles in generalizing the equations. It must be solved by developing an expert system, which may distinguish proper price equations for every specific value chain from top-level buyers to producers as the lowest level. In fact, while international market has already been founded on a structured system, local markets are more likely unstructured (Laib and Radjef, 2011) due to liquid interactions between producers and local traders (Coe, 2006). Any information system must hence be aware with a condition as such to provide highly-accurate price information for farmers. Besides, the system needs to encourage continuous check-and-balances between value chain members. It is critical to prevent any support to ever profit gaining activities by traders that leave producers as the least profit-gainers (Sianipar *et al.*, 2013b).

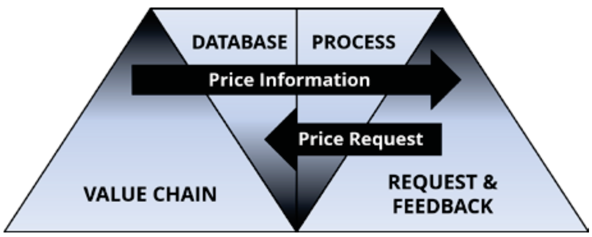


Figure VIII.1. Potential system framework.

Based on these understandings, the system should be founded on four facets (Figure VIII. 1). The first one is value chain, covering a real condition of price derivations from base prices taken in the international commodity markets into local prices throughout the chain. The condition is then compiled into a dedicated database as the second facet, containing equations of price derivation for each existing value chain. Next, the third facet is a compact processing system in which each flow of request is interpreted, calculated, and then delivered back in a human-readable form of information to a producer. Then, the last facet is request-and-feedback. While a request is sent by a producer based on one's preferences on required information, a feedback contains information for being sent back by the process to a requesting producer.

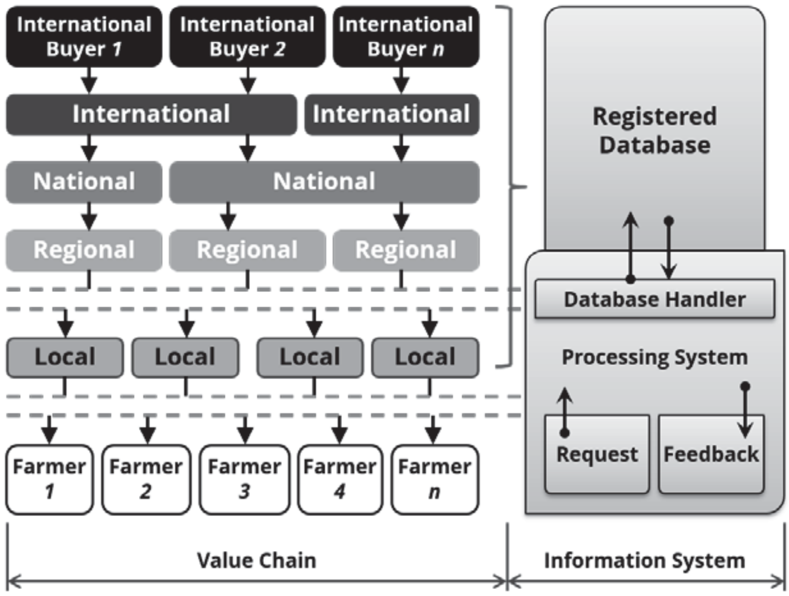


Figure VIII.2. Value chain into an information system.

VIII.2.2 System engineering

VIII.2.2.1 Information system

System behind the whole information is important due to critical roles of social justice elements in providing price information for producers. In general, the system is divided into two big parts (Figure VIII.2). The first part is Value Chain information, covering all value chain members from international buyers to local collectors. In general, international buyers are big companies that have manufacturing plants for making end products from commodities being traded. They develop their supply chains by cooperating with international traders. Next, the traders extend their connection to national traders. National traders are usually owned by the same international traders but with some adaptations required to comply with specific national regulations. They coordinate smaller teams known as regional traders as a further extension of their connections with local traders. Local traders may possibly be independent parties from the international market. Their sole role is to connect the market to producers. As a means for increasing competitiveness, any connection between local traders to producers and higher chains commonly occurs through liquid trading interactions.

Furthermore, the second part is Information System itself, covering two sub-parts, *i.e.* Registered Database (RB) and Processing System (PS). RB compiles value chain alternatives that may exist between each international buyer to local traders. As a means for avoiding “black traders”, registration is required to verify each trader and maintain trading availability. Database is compiled based on both top-down and bottom-up networks. Top-down refers to interconnected parties based on buyers’ database. On the other hand, bottom-up is compiled voluntary by local traders and producers based on their local conditions. The bottom-up registration may also be simply conducted by establishing a coordination with local partners or government to ensure local supports to the system. Coordination may produce reliable data along with reducing required efforts in encouraging a bottom-up data compilation.

Then, PS consists of several processing units to process requests from and deliver feedback to producers. Each processing unit has its own role within the whole PS. The most critical units are database handler, request processors, and feedback sender. The handler conducts compilation and database control. It compiles informative inputs from both top-down and bottom-up and then controls the access and interconnected information. It also acts as the gate of information security, e.g. buyers’ internal data. Next, request processors conduct requests management to distinguish each request based on its type and/or requested information. The processors may exist locally as well as internationally. International request processor manages requests sent by local processor and connect them to database handler. Local processor conducts some locally required process to reduce resources allocation on the whole processing system. Then, feedback sender transforms processed results into a human-readable format and sends the translated outputs back to each specific requesting producer.

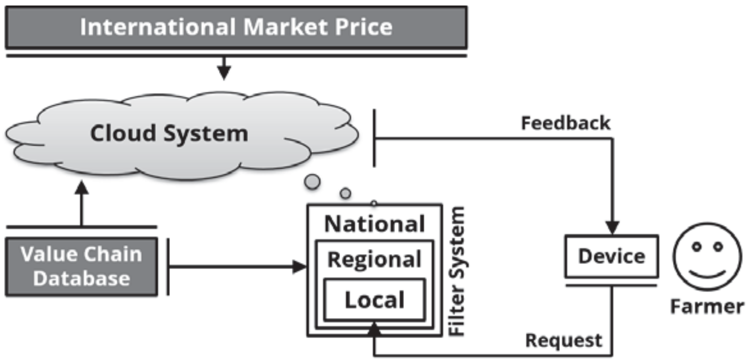


Figure VIII.3. Infrastructure scheme.

VIII.2.2.2 System infrastructures

Then, the system infrastructure is designed by referring to the Information System. The infrastructures consist of four structures (Figure VIII.3). The first is producer's device to send price request and receive price information. By considering financial issues, text-based device is preferred. Hence, formatted text is required. However, an easier procedure may also be taken by using blank text message as the default format. Additional information may also be written if there are specific additional information, e.g. price in other place(s) and/or specific value-chain path. Then, the request is received by second structure, *i.e.* filter system, which is an automatic filter that can locate the position of the sending device. The detection is taken through the station-based of device's cellular number or requester's registration ID provided in the text message. Next, the filter sends its outputs to a cloud system as the main structure. Cloud system is chosen due to potentially-overwhelming requests from covered area to the whole system. Filter and cloud systems are separated to avoid system rush due to the unique characteristics of each request and feedback. A local filter may also be useful to adapt the whole system to national regulations. Then, the last structure is value-chain database. It is a secure system containing all critical data for request and feedback processing. It is connected to both filter and cloud systems. Processing logics are conducted based on compiled database.

Practically, a producer sends a request by using a formatted text message. Text message source is taken from device's position if there is no determined place request. When a price request is sent from a producer's device, it is automatically filtered first to distinguish value-chain path alternatives that may exist from local area to national area. The chains are selected based on registered value chain members in the database. It provides a temporary output on several best alternatives among random existing chains. Next, the output is sent to cloud system for being processed. The cloud system gathers international market prices from real-time commodity stock markets based on alternatives sent by the filter system. The cloud will process those alternatives and connect them into an existing international market network. International market prices are then processed to get the international base price of each value chain alternative. After that, each price is derived throughout its single chain alternative to get a local price. The results are interpreted as price alternatives for a producer to sell one's commodity. Then, cloud system sends the results back to the producer's device with required information, *e.g.* each filtered chain path from local to regional levels and its local price. The information is cut in-between regional and national to avoid a confusing interpretation due to dynamic and fragile conversions, *e.g.* currency exchanges or hourly stock changes. Regional and local chains are required to encourage control and balance from producers to local traders. Then, a transparency from local to regional value chains may pull traders' competitiveness up and hence discourage any local monopoly/monopsony.

VIII.2.3 Required actions and implications

An information system of commodity market prices has been recognized as being critical in delivering social justice for producers. A long value-chain should be transformed into a useful information scheme on the market price of a specific commodity for its producer. The proposed system has four facets (Figure VIII.1). Each facet has its own roles within the whole system. These facets are then interpreted into a system that converts value chain information into an integrated information system (Figure VIII.2). Then, required infrastructures have been explored to build an agile system for processing price requests into feedbacks (Figure VIII.3). Actions are required to implement this initiative into practices. Researches may possibly be conducted in terms of infrastructures study or logics behind decisions on value-chain path designation in processing a request. Policy area is also interesting to explore on how to connect interests of many value chain members from producers to top-level buyers.

Looking at diagrams provided in this study (Figure VIII.1 and Figure VIII.2), implications are mostly directed to national governments of involved countries. National governments as the highest regulator at national level as well as the strongest negotiator at international level has the most critical position in the system. At national level, government should encourage regional and local governments to establish a bottom-up database compilation. Local infrastructures adapted from this study (Figure VIII.3) to national regulation are dependent to the decision of a national government. Despite, for example, within a fully autonomous or remote area, government is a neutral party to build required infrastructures. At international level, suppliers and demanders can be easily distinguished. Intermediate distributors can also be determined from value chains. Thus, national government must act as a strategic negotiator in developing adapted equations for price derivation to pursue social justice for producers.

MEETING ATTENDANCES

The 2nd International Conferences on Geological, Geographical, Aerospace and Earth Sciences (AeroEarth), Bali – Indonesia, 11-12 October 2014.

The 3rd International Conference on Communication and Computer Engineering (ICOCOE), Bandung – Indonesia, 15-17 March 2016.

The 2nd International Congress on Economics, Social Sciences and Information Management (ICESSIM), Bali – Indonesia, 19-20 March 2016.

The 3rd International Conference on Agricultural and Food Engineering (CAFEi), Kuala Lumpur – Malaysia, 23-25 August 2016.

REFERENCES

Adger, W.N., and Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience*, *337*(4), 399-410.

Adger, W.N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268-281.

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change*, *26*(3), 413-439.

Ahmed, S.A., Diffenbaugh, N.S., and Hertel, T.W. (2009). Climate volatility deepens poverty vulnerability in developing countries. *Environmental Research Letters*, *4*(3), 034004.

Akubue, A. (2000). Appropriate technology for socioeconomic development in Third-World countries. *Journal of Technology Studies*, *26*(1).

Alsop, R., and Kurey, B. (2005). *Local organizations in decentralized development: Their functions and performance in India*. Washington D.C., US: The World Bank.

Alsop, R., Bertelsen, M.F., and Holland, J. (2006). *Empowerment in practice: From analysis to implementation*. Washington D.C., US: The World Bank.

Amexo, M., Tolhurst, R., Barnish, G., and Bates, I. (2004). Malaria misdiagnosis: Effects on the poor and vulnerable. *The Lancet*, *364*(9448), 1896-1898.

Amin (2009). *Teknik pengeringan kakao*. Nias, ID: Swisscontact.

Amir, S. (2013). *The technological state in Indonesia: The co-constitution of high technology and authoritarian politics*. New York, UK: Routledge.

Amstrong, T. (1997). *Design for Sustainability*. Toronto, CA: IndEco Strategic Consulting Inc.

Andersen, P.T., Jørgensen, S.K., and Larsen, E.L. (2011). For the sake of health! Reflections on the contemporary use of social capital and empowerment in Danish health promotion policies. *Social Theory Health*, *9*(1), 87-107.

Annells, M. (1996). Grounded theory method: Philosophical perspectives, paradigm of inquiry, and postmodernism. *Qualitative Health Research*, *6*(3), 379-393.

Asia Pulse (2011, February 3). Indonesia to become world's largest cocoa producer. *Asia Pulse*. Rhodes, AU: Asia Pulse Pty Ltd.

Bailie, C. (2006). *Engineers within a local and global society*. California. US: Morgan & Claypool.

Baranson, J. (1978). *Technology and the multinationals: Corporate strategies in a changing world economy*. Lexington, US: Lexington Books.

Bayazit, N. (2004). Investigating design: A review of forty years of design research. *Design Issues 20*(1), 16-29.

Betz, M.J., McGowan, P., Wigand, R.T. (Eds.). (1984). *Appropriate technology: Choices and development*. Durham, UK: Duke University Press.

Bhagavan, M. (1979). A critique of 'appropriate' technology for underdeveloped countries. *Research Report 48*. Uppsala, SE: The Scandinavian Institute of African Studies.

Boehlje, M. (1999). Structural changes in the agricultural industries: How do we measure, analyze and understand them?. *American Journal of Agricultural Economics*, ***81***(5), 1028-1041.

Boehm, B., and Turner, R. (2003). *Balancing agility and discipline: A guide for the perplexed*. Boston, US: Addison-Wesley Professional.

Bonner, J.T. (1958). *The evolution of development*. Cambridge, UK: Cambridge University Press.

Bourdelais, P. (2005). What is vulnerability? *Annales de Démographie Historique*, *110*(2), 11-15.

Bourrieres, P. (1979). Adaptation of technologies to available resources. In: A. Robinson (Ed.), *Appropriate technologies for Third World development* (pp. 1-7). New York, US: St. Martin's Press.

Boom, S. (2005). *Affordable lightning for people living in rural areas of Cambodia: Design of a solar lantern for the Cambodian market*. Deflt, NL: TU Delft.

Brezet, H., and Hemel, C.v. (1997). *Ecodesign: A promising approach to sustainable production and consumption*. Paris, FR: Renouf Publishing.

Brockington, D. (2007). Forests, community conservation, and local government performance: The village forest reserves of Tanzania. *Society and Natural Resources*, *20*(9), 835-848.

Brooks, H. (1980). A critique of the concept of appropriate technology. In: F. Long and A. Oleson (Eds.), *Appropriate technology and social values: A critical appraisal* (pp. 53-78). Cambridge, US: Ballinger.

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. *Tyndall Centre for Climate Change Research Working Paper*, *38*, 1-16.

Bruun, P., and Mefford, R.N. (1996). A framework for selecting and introducing appropriate production technology in developing countries. *International Journal of Production Economics*, *46-47*, 197-209.

Carley, M., and Christie, I. (1993). *Managing sustainable development*. Minneapolis, US: University of Minnesota Press.

Catalano, G.D. (2006). *Engineering, poverty, and the Earth*. California, US: Morgan & Claypool.

Chandra, V. (Ed.) (2006). *Technology, Adaptation, and Exports – How some developing countries got it right*. Washington D.C., US: The World Bank.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. California, US: SAGE Publications.

Chaudhuri, S., Jalan, J., and Suryahadi, A. (2002). Assessing household vulnerability to poverty from cross-sectional data: A methodology and estimates from Indonesia. *Department of Economics Discussion Papers*, *0102-52*, 1-36. Columbia, US: Columbia University.

Christenhusz, M.J.M., and Byng, J.W. (2016). The number of known plants species in the world and its annual increase. *Phytotaxa*, *261*(3), 201–217.

Clark, N.G (1985). *The political economy of science and technology*. Oxford, UK: Blackwell.

Clark, G., Kosoris, J., Hong, L.N., and Crul, M. (2009). Design for Sustainability: Current trends in sustainable product design and development. *Sustainability* *1*(1): 409-424.

Clay, J. (2004). *World agriculture and the environment*. Washington DC, US: Island Press.

Coe, S.D., and Coe, M.D. (1996). *The true history of chocolate*. London, UK: Thames & Hudson.

Coe, C.A. (2006). Farmer participation in market authorities of coffee exporting countries. *World Development*, *34*(12), 2089-2115.

CoMC (2007). *Chocolate history timeline*. Retrieved from goo.gl/2JEcsw on 10 January 2013.

Comfort, L., Wisner, B., Cutter, S., Pulwarty, R., Hewitt, K., Oliver-Smith, A., and Krimgold, F. (1999). Reframing disaster policy: The global evolution of vulnerable communities. *Environmental Hazards*, *1*(1), 39-44.

Conley, T. (2009). *The vulnerable country: Australia and the global economy*. Sidney, AU: University of New South Wales Press.

Cornwall, A., and Edwards, J. (2010). Introduction: Negotiating empowerment. *IDS Bulletin*, *41*(2), 1-9.

Cova, T.J. (1999). GIS in emergency management. *Geographical Information Systems*, *2*, 845-858.

Cowen, M.P., and Shenton, R.W. (1998). Agrarian doctrines of development: Part I. *Journal of Peasant Studies*, *25*(2), 49-76.

Cross, N. (Ed.). (1984). *Developments in design methodology*. Chichester, UK: John Wiley & Sons.

Cross, N. (2011). *Design Thinking: Understanding how designers think and work*. Oxford, UK: Berg.

Crul, M. (2003). *Ecodesign in Central America*. Delft, NL: TU Delft Design for Sustainability Publications.

Cummings, S.L. (2001). Community economic development as progressive politics: Toward a grassroots movement for economic justice. *Stanford Law Review*, *54*, 399-493.

Cutter, S.L., Boruff, B.J., and Shirley, W.L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2), 242-261.

Darrow, K., and Saxenian, M. (1986). *Appropriate technology sourcebook: A guide to practical books for village and small community technology*. Stanford, US: Volunteers in Asia.

Dasgupta, A., and Beard, V.A. (2007). Community driven development, collective action and elite capture in Indonesia. *Development and Change*, *38*(2), 229-249.

Dechezleprêtre, A., Glachant, M., and Ménière, Y. (2009). Technology transfer by CDM projects: A comparison of Brazil, China, India and Mexico. *Energy Policy*, *37*(2), 703-711.

DeFilippo, J.S. (1997). World-class manufacturing in Chengdu: a case study on China's first aviation joint venture. *International Journal of Technology Management*, *13*(5), 681-694.

Dhoedt, A. (2010). "Food of the Gods": The rich history of chocolate. *AgroFOOD Industry Hi-Tech*, *20*(6), 2-5.

Díaz-Puente, J.M., Montero, A.C., and De los Ríos Carmenado, I. (2009). Empowering communities through evaluation: Some lessons from rural Spain. *Community Development Journal*, *44*(1), 53-67.

Diehl, J., and Kuipers, H. (2008). Design for the base of the pyramid: Student field projects in Cambodia. *Proceedings of DesignED Asia Conference 2008*. Hong Kong, CN.

Dillinger, T.L., Barriga, P., Escárcega, S., Jimenez, M., Lowe, D.S., and Grivetti, L.E. (2000). Food of the gods: cure for humanity? A cultural history of the medicinal and ritual use of chocolate. *The Journal of Nutrition*, *130*(8), 2057S-2072S.

Donald, P.F. (2004). Biodiversity impacts of some agricultural commodity production systems. *Conservation Biology*, *18*, 17-37.

Dorward, A., Fan, S., Kydd, J., Lofgren, H., Morrison, J., Poulton, C., Rao, N., Smith, L., Tchale, H., Thorat, S., and Urey, I. (2004). Institutions and policies for pro-poor agricultural growth. *Development Policy Review*, *22*(6), 611-622.

Downing, T.E. (1992). *Climate change and vulnerable places: Global food security and country studies in Zimbabwe, Kenya, Senegal and Chile*. Available at http://goo.gl/TiU5O0. Oxford, UK: Environmental Change Unit – University of Oxford.

Dunmade, I. (2002). Indicators of sustainability: Assessing the suitability of a foreign technology for a developing economy. *Technology in Society*, *24*(4), 461-471.

Dunn, P.D. (1978). *Appropriate technology: Technology with a human face*. New York, US: Schoken Books.

Eade, D. (1997). *Capacity-building: an approach to people-centred development*. London, UK: Oxfam.

Edoho, F.M. (2009). Appropriate technology transfer. *Institutional Issues Involving Ethics and Justice 2*, 123-136.

Ehrenfeld, J.R. (2008). *Sustainability by design: A subversive strategy for transforming our consumer culture*. Connecticut, US: Yale University Press.

Eicher, T.S. (1999). Training, adverse selection and appropriate technology: Development and growth in a small open economy. *Journal of Economic Dynamics and Control*, *23*(5), 727-746.

Eisenman, D.P., Cordasco, K.M., Asch, S., Golden, J.F., and Glik, D. (2007). Disaster planning and risk communication with vulnerable communities: Lessons from Hurricane Katrina. *American Journal of Public Health*, *97*(Supplement 1), S109-S115.

Ernst, D. (2002). Global production networks and the changing geography of innovation systems: Implications for developing countries. *Economics of Innovation and New Technology*, *11*(6), 497-523.

Escobar, A. (1992). Reflections on ‘development’: Grassroots approaches and alternative politics in the Third World. *Futures*, *24*(5), 411-436.

Evrard, D., Mathieux, F., and Wood, D. (2009). Sustainability and adapted product Eco-Design in small islands developing states in the South Pacific: Teachings of the first case Study in Fiji. *Proceedings of the 11th Pacific Science International-Congress*. Tahiti, PF.

Eyben, R. (2004). "Linking power and poverty reduction", in R. Alsop (Ed.), *Power, Rights, and Poverty: Concepts and Connections*, pp. 15-28. Washington D.C., US: The World Bank.

Fawcett, S.B., Paine-Andrews, A., Francisco, V.T., Schultz, J.A., Richter, K.P., Lewis, R.K., Williams, E.L., Harris, K.J., Berkley, J.Y., Fisher, J.L., and Lopez, C.M. (1995). Using empowerment theory in collaborative partnerships for community health and development. *American Journal of Community Psychology*, *23*(5), 677-697.

Feinblatt, E. (2013). *Update*. Retrieved from http://goo.gl/sG4ovp on 6 November, 2013.

Feng, Y. (2001). Political freedom, political instability, and policy uncertainty: A study of political institutions and private investment in developing countries. *International Studies Quarterly*, *45*(2), 271-294.

Ferguson, L.J. (2010). Transformational empowerment: Change your world from the inside out. *Interbeing*, *4*(2), 35-37.

Few, R. (2003). Flooding, vulnerability and coping strategies: local responses to a global threat. *Progress in Development Studies*, *3*(1), 43-58.

Fields, G.S. (2002). *Distribution and development: A new look at the developing world*. Boston, US: MIT Press.

Figueira, A., Janick, J., and BeMiller, J.N. (1993). *New products from Theobroma cacao: Seed pulp and pod gum*. New crops. New York, US: Wiley.

Fiksel, J. (ed.) (1996). *Design for Environment*. US: McGraw-Hill.

Friedmann, J. (1992). *Empowerment: The politics of an alternative development*. Oxford, UK: Basil Blackwell.

Fritsch, A., and Gallimore, P. (2007). *Healing Appalachia: Sustainable living through appropriate technology*. Kentucky, US: The University Press of Kentucky.

Füssel, H.M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, *17*(2), 155-167.

Fu, X., Pietrobelli, C., and Soete, L. (2011). The role of foreign technology and indigenous innovation in the emerging economies: Technological change and catching-up. *World Development*, *39*(7), 1204-1212.

Ganguly, D., and Docker, J. (2007). *Rethinking Gandhi and nonviolent relationality: Global perspectives*. New York, US: Routledge.

Garniati, L., Owen, A., Kruijsen, J., Ishadamy, Y., and Wibisono, I. (2014). Interface between appropriate technology and sustainable energy policy in vulnerable societies. *Sustainable Cities and Society*, *12*, 9-15.

Germann, K., and Wilson, D. (2004). Organizational capacity for community development in regional health authorities: a conceptual model. *Health Promotion International*, *19*(3), 289-298.

Glendinning, D.R. (1963). The inheritance of bean size, pod size and number of beans per pod in cocoa (*Theobroma cacao L.*), with a note on bean shape. *Euphytica*, *12*(3), 311-322.

Goodier, R., and Moseson, A. (2013). *Communities move to the center of the design process in a newly proposed methodology*. Retrieved from http://goo.gl/Wm1SX2 on 2 October, 2013.

Graham, L. R. (2006). Anthropologists are obligated to promote human rights and social justice: Especially among vulnerable communities. *Anthropology News*, *47*(7), 4-5.

Gray, D.E. (2004). *Doing research in the real world*. London, UK: SAGE Publications.

Guba, E.G., and Lincoln, Y.S. (1994). Competing paradigms in qualitative research. *Handbook of Qualitative Research*, *2*, 163-194.

Guba, E., and Lincoln, Y. (2005). Paradigmatic controversies, contradictions, and emerging influences. In N. K. Denzin and Y. S. Lincoln (eds.), *The Sage Handbook of Qualitative Research*, 3rd ed. Thousand Oaks, CA: SAGE Publications, pp. 191-215.

Gupta, A.K., Sinha, R., Koradia, D., Patel, R., Parmar, M., Rohit, P., *et al*. (2003). Mobilizing grassroots' technological innovations and traditional knowledge, values and institutions: Articulating social and ethical capital. *Futures*, *35*, 975-987.

Gustafson, K., and Branch, R. M. (1997). *Instructional design models*. New York, US: ERIC Clearinghouse on Information and Technology.

Grübler, A. (1998). *Technology and global change*. Cambridge, UK: Cambridge University Press.

Haase, J.E., and Myers, S.T. (1988). Reconciling paradigm assumptions of qualitative and quantitative research. *Western Journal of Nursing Research*, *10*, 128-137.

Haffmans, S., and Winthagen, V. (2009*). Final report: Cleaner production for better products case studies*. Amsterdam, NL: IdealCo.

Harrison, P. (1980). *The Third-World tomorrow*. London, UK: Penguin Books.

Hart, G. (2001). Development critiques in the 1990s: Culs de sac and promising paths. *Progress in Human Geography*, *25*(4), 649-658.

Haggblade, S., Hazell, P.B., and Reardon, T. (Eds.). (2007). *Transforming the rural nonfarm economy: Opportunities and threats in the developing world*. Baltimore, US: The Johns Hopkins University Press.

Haque, M.S. (1999). The fate of sustainable development under Neo-liberal regimes in developing countries. *International Political Science Review*, 20(2), 197-218.

Hawken, P., Lovins, A., and Lovins, L.H. (1999). *Natural capitalism: Creating the next industrial revolution*. Massachusetts, US: Little Brown and Company.

Hazeltine, B., and Bull, C. (1999). *Appropriate technology: Tools, choices, and implications*. California, US: Academic Press.

Hernández, B.J. (1965). *Insect pollination of cacao (Theobroma cacao L.) in Costa Rica*. Wisconsin, US: University of Wisconsin.

Hodges, R.J., Buzby, J. C., and Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use. *The Journal of Agricultural Science*, *149*(S1), 37-45.

Holzapfel, W.H. (2002). Appropriate starter culture technologies for small-scale fermentation in developing countries. *International Journal of Food Microbiology*, *75*(3), 197-212.

Honadle, B. W. (1981). A capacity-building framework: A search for concept and purpose. *Public Administration Review*, ***41***(5), 575-580.

Hovden, J. (2004). Public policy and administration in a vulnerable society: Regulatory reforms initiated by a Norwegian Commission. *Journal of Risk Research*, *7*(6), 629-641.

Hurst, W.J., Tarka, S.M., Powis, T.G., Valdez, F., and Hester, T. R. (2002). Archaeology: cacao usage by the earliest Maya civilization. *Nature*, *418*(6895), 289-290.

ICCO (2012). *International Cocoa Organization: Annual Report 2012*. London, UK: The International Cocoa Organization.

Jaccard, J., and Jacoby, J. (2010). *Theory construction and model-building skills*. New York, US: The Guilford Press.

James, J. (2014). Is there a renewed role for Appropriate Technology in the new global innovation system? *Journal of International Development*, doi:10.1002/jid.2986

Jequier, N., and Blanc, G. (1983). *The world of appropriate technology*. Paris, FR: Organization for Economic Cooperation and Development.

Just, R.E., & Chern, W.S. (1980). Tomatoes, technology, and oligopsony. *The Bell Journal of Economics*, 584-602.

Juwaini, A. (2013). Peran riset dan teknologi dalam pemberdayaan masyarakat. Paper presented in *Seminar on Technology for the Poor*, 22 February 2013, Jakarta - Indonesia.

Kabeer, N., Mahmud, S., and Castro, J.G.I. (2012). NGOs and the political empowerment of poor people in rural Bangladesh: Cultivating the habits of democracy? *World Development*, *40*(10), 2044-2062.

Kaplinsky, R. (1990). *The economies of small: Appropriate technology in a changing world*. London, UK: Intermediate Technology Publications.

Kaplinsky, R. (2011). Schumacher meets Schumpeter: Appropriate technology below the radar. *Research Policy*, *40*, 193-203.

Kasmel, A., and Andersen, P.T. (2011). Measurement of community empowerment in three community programs in Rapla (Estonia). *International Journal of Environmental Research and Public Health*, *8*(3), 799-817.

Kemp, R. (1994). Technology and the transition to environmental sustainability. *Futures*, *26*(10), 1023-1046.

Kennedy, J., Ashmore, J., Babister, E., and Kelman, I. (2008). The meaning of ‘Build Back Better’: Evidence from post-tsunami Aceh and Sri Lanka. *Journal of Contingencies and Crisis Management*, *16*(1), 24-36.

Khanna, R.K., Rathore, R.S., and Sharma, C. (2008). Solar still an appropriate technology for potable water need of remote villages of desert state of India—Rajasthan. *Desalination*, *220*(1), 645-653.

Kitinoja, L., Saran, S., Roy, S.K., and Kader, A. A. (2011). Postharvest technology for developing countries: Challenges and opportunities in research, outreach and advocacy. *Journal of the Science of Food and Agriculture*, *91*(4), 597-603.

Knack, S., and Keefer, P. (1997). Does social capital have an economic payoff? A cross-country investigation. *The Quarterly Journal of Economics*, *112*(4), 1251-1288.

Kothari, U. (2005a). Authority and expertise: The professionalisation of international development and the ordering of dissent. *Antipode*, *37*(3), 425-446.

Kothari, U. (Ed.). (2005b). *A radical history of development studies*. London, UK: Zed Books.

Krauss, S. E. (2005). Research paradigms and meaning making: A primer. *The Qualitative Report*, *10*(4), 758-770.

Lacy, W.B. (2000). Empowering communities through public work, science, and local food systems: Revisiting democracy and globalization. *Rural Sociology*, *65*(1), 3-26.

Laib, F., and Radjef, M.S. (2011). Automated traders in commodities markets: Case of producer–consumer institution. *Expert Systems with Applications*, *38*(12), 15134-15142.

Lee, M., and Koh, J. (2001). Is empowerment really a new concept? *International Journal of Human Resource Management*, *12*(4), 684-695.

Lee, D.R. (2005). Agricultural sustainability and technology adoption: Issues and policies for developing countries. *American Journal of Agricultural Economics*, *87*(5), 1325-1334.

Lee, K-H. (2009). Why and how to adopt green management into business organizations? *Management Decision*, *47*(7), 1101-1121.

Leichenko, R.M., and O'Brien, K.L. (2002). The dynamics of rural vulnerability to global change: The case of Southern Africa. *Mitigation and Adaptation Strategies for Global Change*, *7*(1), 1-18.

Leiter, J., and Harding, S. (2004). Trinidad, Brazil, and Ghana: Three melting moments in the history of cocoa. *Journal of Rural Studies*, *20*(1), 113-130.

Lin, J.Y., and Zhang, P. (2009). Industrial structure, appropriate technology and economic growth in less developed countries. *Policy Research Working Paper 4905*. Washington DC, US: The World Bank Development Economics Vice Presidency.

Liverman, D. (1990). 'Vulnerability to global environmental change', in R. Kasperson *et al.* (Eds.), *Understanding Global Environmental Change: The Contributions of Risk Analysis and Management*, ch. 4, pp. 27-44. Worcester, US: Clark University.

Lucena, J., Schneider, J., and Leydens, J.A. (2010). *Engineering and sustainable community development*. California, US: Morgan & Claypool.

Lukes, S. (1994). *Power: A radical view*. London, UK: Macmillan Press Ltd.

Luttrell, C., Quiroz, S., Scrutton, C., and Bird, K. (2009). *Understanding and operationalizing empowerment*. London, UK: Overseas Development Institute.

Mamphweli, N.S., and Meyer, E.L. (2009). Implementation of the biomass gasification project for community empowerment at Melani village, Eastern Cape, South Africa. *Renewable Energy*, *34*(12), 2923-2927.

Manion, M., and Evan, W.M. (2002). Technological catastrophes: Their causes and prevention. *Technology in Society*, *24*(3), 207-224.

Mathews, S. (2004). Post-development theory and the question of alternatives: a view from Africa. *Third World Quarterly*, *25*(2), 373-384.

McCullough, E.B., Pingali, P.L., and Stamoulis, K. G. (2008). *The transformation of agri-food systems: Globalization, supply chains and smallholder farmers*. Vancouver, US: Food & Agriculture Organization – the United Nations.

McEntire, D.A. (2005). Why vulnerability matters: Exploring the merit of an inclusive disaster reduction concept. *Disaster Prevention and Management*, *14*(2), 206-222.

Measey, M. (2010). Indonesia: A vulnerable country in the face of climate change. *Global Majority E-Journal*, *1*(1), 31-45.

Mechanic, D., and Tanner, J. (2007). Vulnerable people, groups, and populations: Societal view. *Health Affairs*, *26*(5), 1220-1230.

Mercer, J., Dominey-Howes, D., Kelman, I., and Lloyd, K. (2007). The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards*, *7*(4), 245-256.

Mills, J., Bonner, A., and Francis, K. (2006). The development of constructivist grounded theory. *International Journal of Qualitative Methods*, *5*(1), 1-10.

Minkler, M. (2005). *Community organizing & Community building for health*. London, UK: Rutgers University Press.

Mitchell, T. (1988). *Colonising Egypt*. Cambridge, UK: Cambridge University Press.

Mongkolnchaiarunya, J. (2005). Promoting a community-based solid-waste management initiative in local government: Yala municipality, Thailand. *Habitat International*, *29*(1), 27-40.

Moore, C. (1994). *Images of development: Egyptian engineers in search of industry*. Cairo, EG: The American University of Cairo Press.

Moose, D. (2004). "Power relations and poverty reduction", in R. Alsop (Ed.), *Power, Rights, and Poverty: Concepts and Connections*, pp. 51-67. Washington D.C., US: The World Bank.

Morawetz, D. (1974). Employment implications of industrialization in developing countries: A survey. *The Econonomic Journal 84*(335), 491-542.

Moreno, M.P. (2011). A bittersweet love affair: Spain and the history of chocolate. Connections. *European Studies Annual Review*, *7*, np.

Morgan, G. (1983). "Research strategies: Modes of engagement." In G. Morgan (ed.), *Beyond method*. Beverly Hills, CA: SAGE Publications.

Morris, M. L. (2007). *Fertilizer use in African agriculture: Lessons learned and good practice guidelines*. World Bank Publications.

Morrow, B.H. (1999). Identifying and mapping community vulnerability. *Disasters*, *23*(1), 1-18.

Morse, S. (2008). Post-sustainable development. *Sustainable Development*, *16*(5), 341-352.

Moser, G., Leuschner, C., Hertel, D., Hölscher, D., Köhler, M., Leitner, D., Michalzik, B., Prihastanti, E., Tjitrosemito, S., and Schwendenmann, L. (2010). Response of cocoa trees (Theobroma cacao) to a 13-month desiccation period in Sulawesi, Indonesia. *Agroforestry Systems*, *79*(2), 171-187.

Murray-Li, T. (2002). Local histories, global markets: Cocoa and class in upland Sulawesi. *Development and Change*, *33*(3), 415-437.

Murphy, H.M., McBean, E.A., and Farahbakhsh, K. (2009). Appropriate technology–A comprehensive approach for water and sanitation in the developing world. *Technology in Society*, *31*(2), 158-167.

Narayan, D., Patel, R., Schafft, K., Rademacher, A., and Koch-Schulte, S. (2000). *Voices of the poor: Can anyone hear us?* New York, US: Oxford University Press and the World Bank.

Narayan, D. (Ed.) (2005). *Measuring empowerment: Cross-disciplinary perspectives*. Washington D.C., US: World Bank.

Narayana, N. (2003). Making technologies work for the poor in developing countries. *Botswana Journal of African Studies 17*(2), 26-34.

Neuman, W.L. (2006). *Social research methods: Qualitative and quantitative approaches* (7th ed.). Boston, US: Allyn & Bacon (Pearson).

Ng, R. (2011). A speed date with chocolate. *Chemical Engineering Progress*, *107*(7), 17-21.

Okejiri, E. (2000). Foreign technology and development of indigenous technological capabilities in the Nigerian manufacturing industry. *Technology in Society*, *22*(2), 189-199.

Otto, K.N., and Wood, K.L. (1998). Product evolution: A reverse engineering and redesign methodology. *Research in Engineering Design*, *10*(4), 226-243.

Otto, K.N., and Wood, K.L. (2001). *Product design: Techniques in reverse engineering and new product development*. New York, US: Prentice Hall.

Page, N., and Czuba, C.E. (1999). Empowerment: What is it? *Journal of Extension*, *37*(5), 1-5.

Pahl, G., and Beitz, W. (1984). *Engineering design: A systematic approach*. Berlin, DE: Springer.

Pahl, G., Beitz, W., Feldhusen, J., and Grote, K-H. (2007). *Engineering design: A systematic approach* (3rd ed.). Berlin, DE: Springer.

Pandya, C. (2006). Private authority and disaster relief: The cases of post-tsunami Aceh and Nias. *Critical Asian Studies*, *38*(2), 298-308.

Park, E. and Ohm, J.Y. (2015). Appropriate technology for sustainable ecosystems: Case studies of energy self-reliant villages and the future of the energy industry. *Sustainable Development*, *23*(2), 74-83.

Pearson, J. (2006). *Design and sustainability: Opportunities for systemic transformation*. Virginia, US: GreenBlue.

Pellegrini, U. (1979). The problem of appropriate technology. In A. de Giorgio and C. Roveda (Eds.), *Criteria for selecting appropriate technologies under different cultural, technical and social conditions* (pp. 1-5). New York, US: Pergamon Press.

Philips, R., and Pittman, R.H. (2009). *An introduction to community development*. New York, US: Taylor and Francis.

Pieterse, J.N. (2000). After post-development. *Third World Quarterly*, *21*(2), 175-191.

Plenert, G. (1997). Requirements for technology transfer to Third World countries. *International Journal of Technology Management*, *13*(4), 421-425.

Power, G., Maury, M., and Maury, S. (2002). Operationalising bottom-up learning in international NGOs: Barriers and alternatives. *Development in Practice*, *12*(3-4), 272-284.

Prastowo (2013). Aplikasi Teknologi Tepat Guna dalam pemberdayaan masyarakat. Paper presented in *Seminar on Technology for the Poor*, 22 February 2013, Jakarta - Indonesia.

Pretty, J.N. (1995). Participatory learning for sustainable agriculture. *World Development*, ***23***(8), 1247-1263.

PRB (2014). *World population datasheet 2013*. Available at http://goo.gl/vXIY0a. Washington DC, US: Population Reference Bureau.

Pursell, C. (1993). The rise and fall of the appropriate technology movement in the United States: 1965-1985. *Technology and Culture 34*(3), 629-637.

Putranto, K., Stewart, D., and Moore, G. (2003). International technology transfer and distribution of technology capabilities: The case of railway development in Indonesia. *Technology in Society*, *25*(1), 43-53.

Qadir, M., & Oster, J. D. (2004). Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. *Science of the Total Environment*, ***323***(1), 1-19.

Rahnema, M., and Bawtree, V. (1997). *The post-development reader*. London, UK: Zed Books.

Rai, N., and Henshaw, C. (2011, April 6). Indonesia, Ghana may fill cocoa void. *Wall Street Journal*. Available at http://goo.gl/OYa68

Raillon, F. (1990). *Indonesia 2000: The industrial and technological challenge*. Jakarta, ID: Cipta Kreatip.

Reardon, T., and Timmer, C. P. (2007). Transformation of markets for agricultural output in developing countries since 1950: How has thinking changed?. *Handbook of Agricultural Economics*, *3*, 2807-2855.

Reiser, R. A. (2001). A history of instructional design and technology: Part II: A history of instructional design. *Educational Technology Research and Development*, *49*(2), 57-67.

Renting, H., Marsden, T.K., & Banks, J. (2003). Understanding alternative food networks: exploring the role of short food supply chains in rural development. *Environment and Planning A*, ***35***(3), 393-411.

Richardson, A. (2010). *Innovation X: Why a company's toughest problems are its greatest advantage*. San Francisco, US: Jossey-Bass.

Rifkin, S.B. (2003). A framework linking community empowerment and health equity: It is a matter of CHOICE. *Journal of Health Population Nutrition*, *21*(3), 168-180.

Rigg, J., Law, L., Tan-Mullins, M.A.Y., and Grundy-Warr, C.A.R.L. (2005). The Indian Ocean tsunami: Socio-economic impacts in Thailand. *The Geographical Journal*, *171*(4), 374-379.

Riley, D. (2008). *Engineering and social justice*. California, US: Morgan & Claypool.

Rip, A. (1995). Introduction of new technology: Making use of recent insights from sociology and economics of technology. *Technology Analysis & Strategic Management*, *7*(4), 417-432.

Rip, A., and Kemp, R. (1998). 'Technological Change', in S. Rayner and L. Malone (eds.) *Human Choice and Climate Change*, vol. 2: Resources and Technology, 327-399; Washington D.C., US: Batelle Press.

Rist, G. (2002). *The history of development from Western origins to global faith*. London, UK: Zed Books.

Rist, G. (2007). Development as a buzzword. *Development in Practice*, *17*(4-5), 485-491.

Robards, M., and Alessa, L. (2004). Timescapes of community resilience and vulnerability in the circumpolar north. *Arctic*, *57*(4), 415-427.

Rochman, N.T. (2013). Nanoteknologi, technology for the poor: Tepat guna dan memberdayakan. Paper presented in *Seminar on Technology for the Poor*, 22 February 2013, Jakarta - Indonesia.

Rodenburg, J., Zwart, S.J., Kiepe, P., Narteh, L.T., Dogbe, W., and Wopereis, M.C. (2014). Sustainable rice production in African inland valleys: Seizing regional potentials through local approaches. *Agricultural Systems*, *123*, 1-11.

Rogers, R. T., & Sexton, R. J. (1994). Assessing the importance of oligopsony power in agricultural markets. *American Journal of Agricultural Economics*, ***76***(5), 1143-1150.

Rosenau, P. V. (1994). Health politics meets Post-Modernism: Its meaning and implications for community health organizing. *Journal of Health Politics*, *19*(2), 303-333.

Rosenbrock, H. (1979). The redirection of technology. In A. de Giorgio A and C. Roveda (Eds.), *Criteria for selecting appropriate technologies under different cultural, technical and social conditions* (pp. 7-3). New York, US: Pergamon Press.

Rogers, E. (1995). *Diffusion of Innovations*, 4th ed. New York, US: Free Press.

Ruf, F., and Ehret, P. (1996). Smallholder cocoa in Indonesia: Why a cocoa boom in Sulawesi?. In *Cocoa Pioneer Fronts since 1800* (pp. 212-231). London, UK: Palgrave Macmillan.

Ruf, F., and Schroth, G. (2004). Chocolate forests and monocultures: a historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In *Agroforestry and Biodiversity Conservation in Tropical Landscapes* (pp107-134). Washington DC, US: Island Press.

Rybczynski, W. (1982). Paper heroes: A review of appropriate technology. *Chain Reaction* (27), 38-39.

Sampat, P. (1995). India's low-tech energy success. *World Watch 8*(6), 21-23.

Schrag, F. (1992). In defense of positivist research paradigms. *Educational Researcher*, *21*(5), 5-8.

Schumacher, E.F. (1973). *Small is beautiful: Economics as if people mattered*. Virginia, US: Hartley & Marks Publishers.

Schuurman, F.J. (2000). Paradigms lost, paradigms regained? Development studies in the twenty-first century. *Third World Quarterly*, *21*(1), 7-20.

Schwandt, T.A. (1994). Constructivist, interpretivist approaches to human inquiry. In N. K. Denzin, Y. S. Lincoln, S. Yvonna (eds.), *Handbook of Qualitative Research*. Thousand Oaks, CA: SAGE Publications, pp. 118-137.

Sclove, R. (1995). *Democracy and Technology*. New York, US: The Guilford Press.

Seyfang, G., and Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, *16*(4), 584-603.

Sianipar, C.P.M., and Widaretna, K. (2012). NGO as Triple-Helix axis: Some lessons from Nias community empowerment project on cocoa production. *Procedia – Social and Behavioral Sciences*, *52*, 197-206.

Sianipar, C.P.M., Yudoko, G., Adhiutama, A., and Dowaki, K. (2013a). Community empowerment through appropriate technology: Sustaining the sustainable development. *Procedia Environmental Sciences*, *17*, 1007-1016.

Sianipar, C.P.M., Dowaki, K., Yudoko, G., and Adhiutama, A. (2013b). Seven pillars of survivability: Appropriate technology with a human face. *European Journal of Sustainable Development*, *2* (4), 1-18.

Sianipar, C.P.M., Yudoko, G., Dowaki, K., and Adhiutama, A. (2013c). Design methodology for Appropriate Technology: Engineering as if people mattered. *Sustainability*, *5*(8), 3382-3425.

Sianipar, C. P. M., Yudoko, G., and Dowaki, K. (2014a). Materials research in Appropriate Technology: In the midst of science, engineering, and technology. *Key Engineering Materials*, *594-595*, 334-338.

Sianipar, C.P.M., Yudoko, G., and Dowaki, K. (2014). Environmental forensics on Appropriate-Technology-enhanced supply chain of rural commodities. In *From Sources to Solution* (pp. 55-60), A.Z. Aris, T.H. Tengku Ismail, R. Harun, A.M. Abdullah, and M.Y. Ishak, eds. Singapore, SG: Springer.

Sidaway, J.D. (2007). Spaces of post-development. *Progress in Human Geography*, *31*(3), 345-361.

Simoes, A. F., Kligerman, D. C., La Rovere, E. L., Maroun, M. R., Barata, M., & Obermaier, M. (2010). Enhancing adaptive capacity to climate change: The case of smallholder farmers in the Brazilian semi-arid region. *Environmental Science & Policy*, ***13***(8), 801-808.

Simon, D. (2007). Beyond anti-development: Discourses, convergences, practices. *Singapore Journal of Tropical Geography*, *28*(2), 205-218.

Skyttner, L. (2005). *General systems theory: Problems, perspectives, practice*. Singapore, SG: World Scientific Publishing Company.

Smith, A., Fressoli, M., and Thomas, H. (2014). Grassroots innovation movements: Challenges and contributions. *Journal of Cleaner Production*, *63*, 114-124.

Snodgrass, M.E. (2003). *Coins and currency: An historical encyclopedia*. North Carolina, US: McFarland.

Souza, R., Bernatsky, S., Reyes, R., and Jong, K. D. (2007). Mental health status of vulnerable tsunami-affected communities: A survey in Aceh Province, Indonesia. *Journal of Traumatic Stress*, *20*(3), 263-269.

Steenhuis, H.-J., and de Bruijn, E.J. (2001). Developing countries and the aircraft industry: match or mismatch? *Technology in Society*, *23*, 551–562.

Stiles, K. (2002). International support for NGOs in Bangladesh: Some unintended consequences. *World Development*, *30*(5), 835-846.

Teitel, S. (1978). On the concept of appropriate technology for less industrialized countries. *Technological Forecasting and Social Change 11*(4), 349-369.

Thormann, P. (1979). Proposal for a program in appropriate technology. In A. Robinson (Ed.), *Appropriate technologies for Third World development* (pp. 280-299). New York, US: St. Martin's Press.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, ***418***(6898), 671-677.

Tobin, G.A., and Montz, B.E. (2004). 'Natural hazards and technology: Vulnerability, risk, and community response in hazardous environments', in Brunn SD, Cutter SL, & Harrington JW (Eds.), *Geography and Technology*, ch. 23, pp. 547-570. Netherlands: Springer.

Todaro, M.P. (1997). Urbanization, unemployment, and migration in Africa: Theory and policy. *Policy Research Division Working Papers*, *104*, 1-50. New York, US: Population Council.

Todd, D., and Simpson, J. (1986). *The world aircraft industry*. London, UK: Croom Helm Ltd.

Tracy, W., Harachi, C.D., Ayers, J.D., Hawkins, R.F., Cushing, C., and Cushing, J. (1996). Empowering communities to prevent adolescent substance abuse: Process evaluation results from a risk- and protection-focused community mobilization effort. *Journal of Primary Prevention*, *16*(3), 233-254.

Turner, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., and Schiller, A. (2003a). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, 100(14), 8074-8079.

Turner, B. L., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A., Selin, H., and Tyler, N. (2003). Illustrating the coupled human–environment system for vulnerability analysis: Three case studies. *Proceedings of the National Academy of Sciences*, *100*(14), 8080-8085.

Ülrich, T. (2009). *Cocoa post-harvest technology assessment*. Unpublished assessment. Nias, ID: Swisscontact.

Vermaas, P., Kroes, P., van de Poel, I., Franssen, M., and Houkes, W. (2011). *A philosophy of technology: From technical artefacts to sociotechnical systems*. California, US: Morgan & Claypool.

Wacker, J.G. (1998). A definition of theory: Research guidelines for different theory-building research methods in operations management. *Journal of Operations Management*, *16*, 361-385.

Wacker, J.G. (2004). A theory of formal conceptual definitions: Developing theory-building measurement instruments. *Journal of Operations Management*, *22*, 629-650.

Wajcman, J. (1995). 'Feminist Perspectives on Technology', in Teich A (Ed.), *Technology and the Future* (7th eds.), ch. 18, pp. 67-79. California, US: Thomson Wadsworth.

Walker, S. (2002). A journey in design: An exploration of perspectives for sustainability. *Journal Sustainable Product Design, 2*(1-2), 3-10.

Watson, E.E., Adams, W.M., & Mutiso, S.K. (1998). Indigenous irrigation, agriculture and development, Marakwet, Kenya. *Geographical Journal*, 67-84.

Weick, C.W., and Walchli, S.B. (2002). Genetically engineered crops and foods: Back to the basics of technology diffusion. *Technology in Society*, *24*(3), 265-283.

Wibowo, H.T. (2013). IbM Kelompok Usaha Nelayan Tradisional desa Limbangan, Balongan, Indramayu. Paper presented in *Seminar on Technology for the Poor*, 22 February 2013, Jakarta - Indonesia.

Wickizer, V.D. (1951). Coffee, tea, and cocoa: An economic and political analysis (Vol. 1). Stanford, US: Stanford University Press.

Willoughby, K.W. (1990). *Technology choice: A critique of the appropriate technology movement*. Colorado, US: Westview Press.

Wicklein, R.C. (1998). Designing for appropriate technology in developing countries. *Technology in Society*, *20*(3), 371-375.

Wie, T. K. (2005). The major channels of international technology transfer to Indonesia: an assessment. *Journal of the Asia Pacific Economy*, *10*(2), 214-236.

Wilkie, P., Clark, A., Pennington, R. T., Cheek, M., Bayer, C., and Wilcock, C. C. (2006). Phylogenetic relationships within the subfamily Sterculioideae (Malvaceae/Sterculiaceae-Sterculieae) using the chloroplast gene *ndhF*. *Systematic Botany*, *31*(1), 160-170.

Wilkinson, R., and Pickett, K. (2009). *The Spirit Level: Why more equal societies almost always do better*. London, UK: Allen Lane.

Willis, K. (2005). *Theories and practices of development*. New York, US: Routledge.

Wilson, P.A. (1996). Empowerment: Community economic development from the inside out. *Urban Studies*, *33*(4-5), 617-630.

Wisner, B., and Luce, H.R. (1993). Disaster vulnerability: Scale, power and daily life. *GeoJournal*, *30*(2), 127-140.

Wood, L. (2010, November 30). *Research and Markets: Indonesia Agribusiness Report Q1 2011 - Cocoa Production Growth to 2014/15: 55% and Coffee Production Growth to 2014/15: 10%*. New York, US: Business Wire.

Woodward, A., Hales, S., and Weinstein, P. (1998). Climate change and human health in the Asia Pacific region: who will be most vulnerable? *Climate Research*, *11*(1), 31-38.

World Cocoa Foundation (2014). *Cocoa market update*. Washington DC, US: World Cocoa Foundation.

Wren, D.A. (2005). *The history of management thought*. New York, US: John Wiley & Sons.

Yanful, E.K. (2009). *Appropriate technologies for environmental protection in the developing world*. Dordrecht: NL: Springer.

Yanu, E.P., Luthfiyanti, R., and Kumalasari, R. (2013). Implementasi Teknologi Tepat Guna untuk pemberdayaan masyarakat: Peluang, strategi dan tantangan. Paper presented in *Seminar on Technology for the Poor*, 22 February 2013, Jakarta - Indonesia.

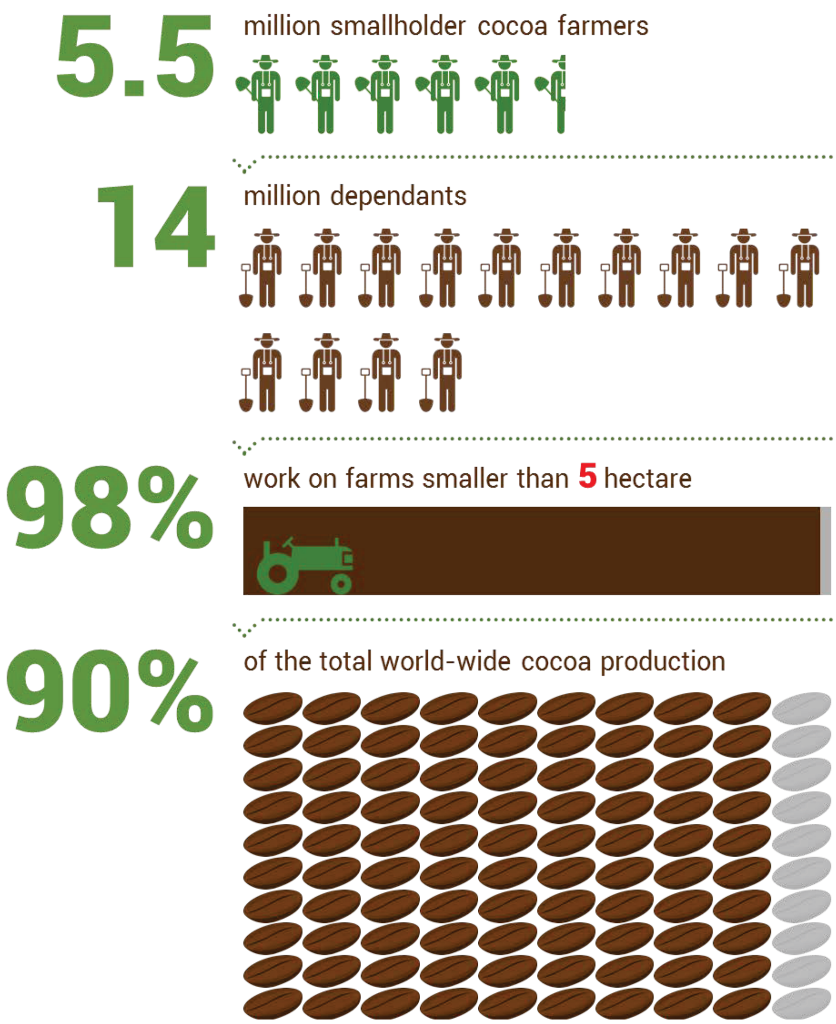
Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Los Angeles, US: Sage Publications.

Yindee, C.A. (2014). Appropriate technology for golden rice farm of Thailand. *Mediterranean Journal of Social Sciences*, *5*(1), 587-593.

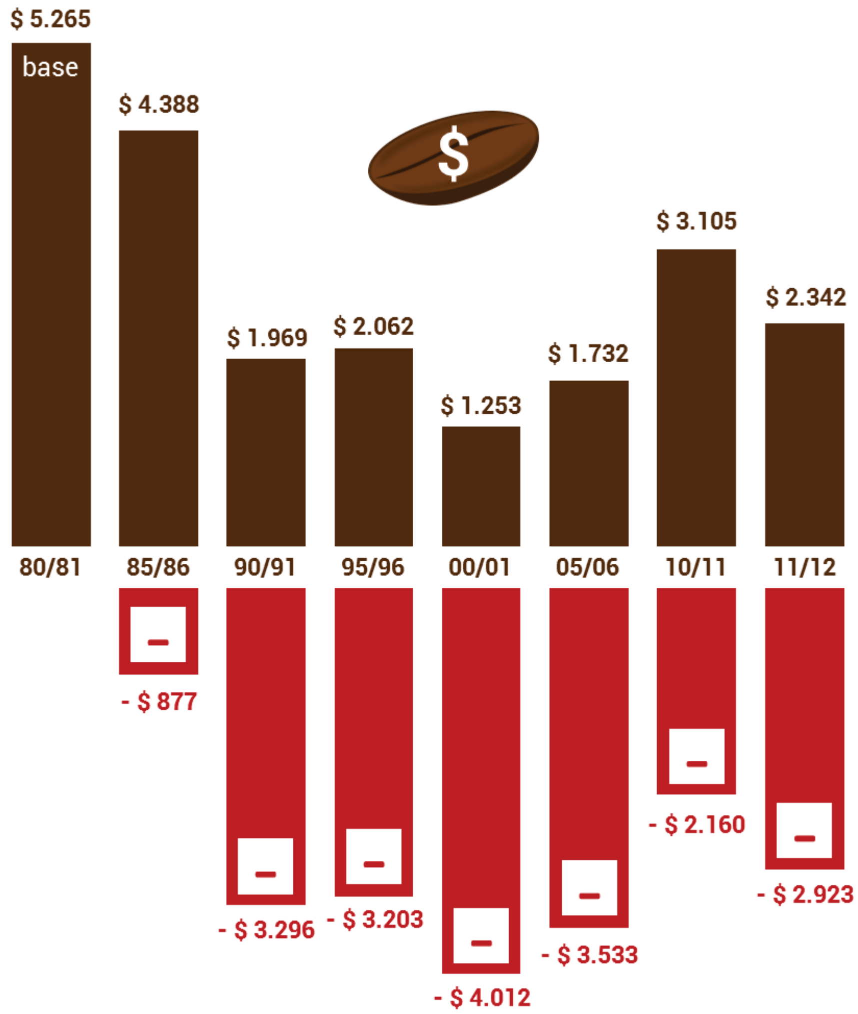
Young, G. (2010). *Design thinking and sustainability*. Sydney, AU: Zumio.

APPENDICES

Appendix 1 Smallholder cocoa farmers and production in the world



Appendix 2 Changes of world's bulk-cocoa prices at producer level [US$/kg]



Appendix 3 Cacao production in Aceh province (2004)

Municipal		2004				
		Plantation Area [ha]	[redacted]	Production [metric ton]	[redacted]	Production Average [kg/ha]
1	Aceh Jaya	347		119		342.94
2	Aceh Singkil	398		28		70.35
3	Aceh Tamiang	681		234		343.61
4	Banda Aceh	0		0		-
5	Bener Meriah	134		8		59.70
6	Bireuen	2,773		2,218		799.86
7	Central Aceh	22		2		90.91
8	East Aceh	2,863		2,254		787.29
9	Gayo Lues	37		16		432.43
10	Greater Aceh	542		52		95.94
11	Langsa	225		150		666.67
12	Lhokseumawe	124		42		338.71
13	Nagan Raya	813		237		291.51
14	North Aceh	2,533		1,268		500.59
15	Pidie	8,906		3,666		411.63
16	Pidie Jaya	-		-		-
17	Sabang	638		98		153.61
18	Simeulue	945		231		244.44
19	Southeast Aceh	749		232		309.75
20	South Aceh	162		18		111.11
21	Southwest Aceh	1,299		330		254.04
22	Subulussalam	-		-		-
23	West Aceh	300		66		220.00

Appendix 4 Cacao production in Aceh province (2005)

	Municipal	2005				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	847	144.09%	104	-12.61%	122.79
2	Aceh Singkil	440	10.55%	58	107.14%	131.82
3	Aceh Tamiang	831	22.03%	201	-14.10%	241.88
4	Banda Aceh	0	-	0	-	-
5	Bener Meriah	134	0.00%	8	0.00%	59.70
6	Bireuen	2,773	0.00%	2,218	0.00%	799.86
7	Central Aceh	22	0.00%	2	0.00%	90.91
8	East Aceh	2,863	0.00%	1,974	-12.42%	689.49
9	Gayo Lues	37	0.00%	16	0.00%	432.43
10	Greater Aceh	534	-1.48%	182	250.00%	340.82
11	Langsa	225	0.00%	150	0.00%	666.67
12	Lhokseumawe	124	0.00%	42	0.00%	338.71
13	Nagan Raya	1,126	38.50%	194	-18.14%	172.29
14	North Aceh	2,533	0.00%	1,268	0.00%	500.59
15	Pidie	8,981	0.84%	3,941	7.50%	438.82
16	Pidie Jaya	-	-	-	-	-
17	Sabang	701	9.87%	231	135.71%	329.53
18	Simeulue	945	0.00%	231	0.00%	244.44
19	Southeast Aceh	1,849	146.86%	960	313.79%	519.20
20	South Aceh	171	5.56%	22	22.22%	128.65
21	Southwest Aceh	1,404	8.08%	345	4.55%	245.73
22	Subulussalam	-	-	-	-	-
23	West Aceh	368	22.67%	48	-27.27%	130.43

Appendix 5 Cacao production in Aceh province (2006)

	Municipal	2006				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	847	0.00%	106	1.92%	125.15
2	Aceh Singkil	444	0.91%	74	27.59%	166.67
3	Aceh Tamiang	976	17.45%	358	78.11%	366.80
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	174	29.85%	10	25.00%	57.47
6	Bireuen	2,845	2.60%	1,998	-9.92%	702.28
7	Central Aceh	109	395.45%	4	100.00%	36.70
8	East Aceh	3,839	34.09%	1,578	-20.06%	411.04
9	Gayo Lues	407	1000.00%	20	25.00%	49.14
10	Greater Aceh	684	28.09%	182	0.00%	266.08
11	Langsa	225	0.00%	150	0.00%	666.67
12	Lhokseumawe	124	0.00%	42	0.00%	338.71
13	Nagan Raya	2,698	139.61%	569	193.30%	210.90
14	North Aceh	2,532	-0.04%	1,179	-7.02%	465.64
15	Pidie	9,230	2.77%	3,941	0.00%	426.98
16	Pidie Jaya	-	-	-	-	-
17	Sabang	638	-8.99%	231	0.00%	362.07
18	Simeulue	727	-23.07%	91	-60.61%	125.17
19	Southeast Aceh	5,764	211.74%	3,503	264.90%	607.74
20	South Aceh	194	13.45%	28	27.27%	144.33
21	Southwest Aceh	1,404	0.00%	345	0.00%	245.73
22	Subulussalam	-	-	-	-	-
23	West Aceh	367	-0.27%	45	-6.25%	122.62

Appendix 6 Cacao production in Aceh province (2007)

	Municipal	2007				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	1,323	56.20%	106	0.00%	80.12
2	Aceh Singkil	565	27.25%	52	-29.73%	92.04
3	Aceh Tamiang	851	-12.81%	179	-50.00%	210.34
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	237	36.21%	45	350.00%	189.87
6	Bireuen	2,925	2.81%	2,472	23.72%	845.13
7	Central Aceh	204	87.16%	4	0.00%	19.61
8	East Aceh	3,090	-19.51%	1,593	0.95%	515.53
9	Gayo Lues	407	0.00%	45	125.00%	110.57
10	Greater Aceh	629	-8.04%	183	0.55%	290.94
11	Langsa	220	-2.22%	145	-3.33%	659.09
12	Lhokseumawe	131	5.65%	59	40.48%	450.38
13	Nagan Raya	3,328	23.35%	569	0.00%	170.97
14	North Aceh	5,077	100.51%	2,268	92.37%	446.72
15	Pidie	10,537	14.16%	3,239	-17.81%	307.39
16	Pidie Jaya	-	-	-	-	-
17	Sabang	638	0.00%	198	-14.29%	310.34
18	Simeulue	1,264	73.87%	103	13.19%	81.49
19	Southeast Aceh	7,587	31.63%	4,578	30.69%	603.40
20	South Aceh	284	46.39%	28	0.00%	98.59
21	Southwest Aceh	1,758	25.21%	348	0.87%	197.95
22	Subulussalam	-	-	-	-	-
23	West Aceh	447	21.80%	78	73.33%	174.50

Appendix 7 Cacao production in Aceh province (2008)

	Municipal	2008				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	1,072	-18.97%	106	0.00%	98.88
2	Aceh Singkil	315	-44.25%	49	-5.77%	155.56
3	Aceh Tamiang	2,065	142.66%	630	251.96%	305.08
4	Banda Aceh		-	-	-	-
5	Bener Meriah	237	0.00%	51	13.33%	215.19
6	Bireuen	2,943	0.62%	2,849	15.25%	968.06
7	Central Aceh	354	73.53%	22	450.00%	62.15
8	East Aceh	3,117	0.87%	1,599	0.38%	512.99
9	Gayo Lues	3,111	664.37%	400	788.89%	128.58
10	Greater Aceh	629	0.00%	183	0.00%	290.94
11	Langsa	202	-8.18%	142	-2.07%	702.97
12	Lhokseumawe	131	0.00%	59	0.00%	450.38
13	Nagan Raya	4,033	21.18%	570	0.18%	141.33
14	North Aceh	6,327	24.62%	3,412	50.44%	539.28
15	Pidie	5,495	-47.85%	1,920	-40.72%	349.41
16	Pidie Jaya	5,048	-	1,779	-	352.42
17	Sabang	638	0.00%	172	-13.13%	269.59
18	Simeulue	1,565	23.81%	131	27.18%	83.71
19	Southeast Aceh	6,906	-8.98%	4,227	-7.67%	612.08
20	South Aceh	390	37.32%	28	0.00%	71.79
21	Southwest Aceh	4,259	142.26%	378	8.62%	88.75
22	Subulussalam	287	-	52	-	181.18
23	West Aceh	654	46.31%	228	192.31%	348.62

Appendix 8 Cacao production in Aceh province (2009)

	Municipal	Plantation Area [ha]	Year-on-year Area Growth [%]	Production [metric ton]	Year-on-year Production Growth [%]	Production Average [kg/ha]
		2009				
1	Aceh Jaya	1,170	9.14%	260	145.28%	222.22
2	Aceh Singkil	496	57.46%	80	63.27%	161.29
3	Aceh Tamiang	2,470	19.61%	1,211	92.22%	490.28
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	737	210.97%	155	203.92%	210.31
6	Bireuen	4,600	56.30%	2,736	-3.97%	594.78
7	Central Aceh	254	-28.25%	36	63.64%	141.73
8	East Aceh	11,939	283.03%	6,808	325.77%	570.23
9	Gayo Lues	4,031	29.57%	363	-9.25%	90.05
10	Greater Aceh	2,289	263.91%	195	6.56%	85.19
11	Langsa	200	-0.99%	174	22.54%	870.00
12	Lhokseumawe	130	-0.76%	55	-6.78%	423.08
13	Nagan Raya	4,051	0.45%	1,343	135.61%	331.52
14	North Aceh	8,603	35.97%	2,692	-21.10%	312.91
15	Pidie	8,247	50.08%	1,911	-0.47%	231.72
16	Pidie Jaya	9,277	83.78%	1,946	9.39%	209.77
17	Sabang	638	0.00%	172	0.00%	269.59
18	Simeulue	1,606	2.62%	100	-23.66%	62.27
19	Southeast Aceh	8,569	24.08%	5,230	23.73%	610.34
20	South Aceh	685	75.64%	70	150.00%	102.19
21	Southwest Aceh	4,096	-3.83%	531	40.48%	129.64
22	Subulussalam	390	35.89%	92	76.92%	235.90
23	West Aceh	653	-0.15%	306	34.21%	468.61

Appendix 9 Cacao production in Aceh province (2010)

	Municipal	2010				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	1,270	8.55%	112	-56.92%	88.19
2	Aceh Singkil	540	8.87%	85	6.25%	157.41
3	Aceh Tamiang	2,604	5.43%	1,152	-4.87%	442.40
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	750	1.76%	109	-29.68%	145.33
6	Bireuen	4,741	3.07%	4,040	47.66%	852.14
7	Central Aceh	1,697	568.11%	253	602.78%	149.09
8	East Aceh	11,998	0.49%	6,972	2.41%	581.10
9	Gayo Lues	4,141	2.73%	363	0.00%	87.66
10	Greater Aceh	2,629	14.85%	277	42.05%	105.36
11	Langsa	272	36.00%	131	-24.71%	481.62
12	Lhokseumawe	135	3.85%	64	16.36%	474.07
13	Nagan Raya	4,993	23.25%	1,415	5.36%	283.40
14	North Aceh	8,603	0.00%	2,680	-0.45%	311.52
15	Pidie	8,247	0.00%	1,421	-25.64%	172.31
16	Pidie Jaya	10,433	12.46%	2,362	21.38%	226.40
17	Sabang	637	-0.16%	172	0.00%	270.02
18	Simeulue	1,870	16.44%	55	-45.00%	29.41
19	Southeast Aceh	9,723	13.47%	6,230	19.12%	640.75
20	South Aceh	830	21.17%	85	21.43%	102.41
21	Southwest Aceh	4,356	6.35%	774	45.76%	177.69
22	Subulussalam	412	5.64%	108	17.39%	262.14
23	West Aceh	653	0.00%	327	6.86%	500.77

Appendix 10 Cacao production in Aceh province (2011)

	Municipal	2011				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	1,270	0.00%	210	87.50%	165.35
2	Aceh Singkil	585	8.33%	107	25.88%	182.91
3	Aceh Tamiang	2,610	0.23%	1,127	-2.17%	431.80
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	933	24.40%	185	69.72%	198.29
6	Bireuen	5,436	14.66%	4,039	-0.02%	743.01
7	Central Aceh	2,300	35.53%	455	79.84%	197.83
8	East Aceh	12,108	0.92%	6,881	-1.31%	568.30
9	Gayo Lues	4,311	4.11%	660	81.82%	153.10
10	Greater Aceh	2,901	10.35%	277	0.00%	95.48
11	Langsa	287	5.51%	132	0.76%	459.93
12	Lhokseumawe	135	0.00%	59	-7.81%	437.04
13	Nagan Raya	5,053	1.20%	1,331	-5.94%	263.41
14	North Aceh	8,603	0.00%	3,056	14.03%	355.22
15	Pidie	9,464	14.76%	4,674	228.92%	493.87
16	Pidie Jaya	10,433	0.00%	2,795	18.33%	267.90
17	Sabang	637	0.00%	172	0.00%	270.02
18	Simeulue	1,890	1.07%	158	187.27%	83.60
19	Southeast Aceh	11,970	23.11%	7,622	22.34%	636.76
20	South Aceh	955	15.06%	106	24.71%	110.99
21	Southwest Aceh	4,356	0.00%	2,746	254.78%	630.39
22	Subulussalam	528	28.16%	108	0.00%	204.55
23	West Aceh	716	9.65%	350	7.03%	488.83

Appendix 11 Cacao production in Aceh province (2012)

	Municipal	2012				
		Plantation Area	Year-on-year Area Growth	Production	Year-on-year Production Growth	Production Average
		[ha]	[%]	[metric ton]	[%]	[kg/ha]
1	Aceh Jaya	1,267	-0.24%	206	-1.90%	162.59
2	Aceh Singkil	636	8.72%	147	37.38%	231.13
3	Aceh Tamiang	2,215	-15.13%	941	-16.50%	424.83
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	1,190	27.55%	185	0.00%	155.46
6	Bireuen	6,023	10.80%	3,801	-5.89%	631.08
7	Central Aceh	2,322	0.96%	546	20.00%	235.14
8	East Aceh	12,416	2.54%	6,536	-5.01%	526.42
9	Gayo Lues	4,443	3.06%	888	34.55%	199.86
10	Greater Aceh	3,129	7.86%	426	53.79%	136.15
11	Langsa	303	5.57%	132	0.00%	435.64
12	Lhokseumawe	135	0.00%	64	8.47%	474.07
13	Nagan Raya	5,372	6.31%	1,335	0.30%	248.51
14	North Aceh	8,603	0.00%	2,730	-10.67%	317.33
15	Pidie	9,599	1.43%	4,499	-3.74%	468.69
16	Pidie Jaya	12,654	21.29%	3,619	29.48%	286.00
17	Sabang	637	0.00%	172	0.00%	270.02
18	Simeulue	1,806	-4.44%	200	26.58%	110.74
19	Southeast Aceh	19,454	62.52%	8,843	16.02%	454.56
20	South Aceh	1,332	39.48%	153	44.34%	114.86
21	Southwest Aceh	4,356	0.00%	874	-68.17%	200.64
22	Subulussalam	816	54.55%	130	20.37%	159.31
23	West Aceh	722	0.84%	235	-32.86%	325.48

Appendix 12 Cacao production in Aceh province (2013)

	Municipal	Plantation Area [ha]	Year-on-year Area Growth [%]	Production [metric ton]	Year-on-year Production Growth [%]	Production Average [kg/ha]
		2013				
1	Aceh Jaya	1,292	1.97%	159	-22.82%	123.07
2	Aceh Singkil	640	0.63%	168	14.29%	262.50
3	Aceh Tamiang	2,031	-8.31%	665	-29.33%	327.42
4	Banda Aceh	-	-	-	-	-
5	Bener Meriah	1,053	-11.51%	332	79.46%	315.29
6	Bireuen	6,671	10.76%	2,559	-32.68%	383.60
7	Central Aceh	2,322	0.00%	786	43.96%	338.50
8	East Aceh	12,484	0.55%	6,684	2.26%	535.41
9	Gayo Lues	4,493	1.13%	902	1.58%	200.76
10	Greater Aceh	3,295	5.31%	426	0.00%	129.29
11	Langsa	301	-0.66%	126	-4.55%	418.60
12	Lhokseumawe	135	0.00%	65	1.56%	481.48
13	Nagan Raya	5,405	0.61%	1,327	-0.60%	245.51
14	North Aceh	8,762	1.85%	3,222	18.02%	367.72
15	Pidie	10,150	5.74%	2,674	-40.56%	263.45
16	Pidie Jaya	13,404	5.93%	4,349	20.17%	324.46
17	Sabang	737	15.70%	193	12.21%	261.87
18	Simeulue	1,598	-11.52%	119	-40.50%	74.47
19	Southeast Aceh	19,994	2.78%	8,843	0.00%	442.28
20	South Aceh	1,332	0.00%	169	10.46%	126.88
21	Southwest Aceh	4,300	-1.29%	567	-35.13%	131.86
22	Subulussalam	826	1.23%	143	10.00%	173.12
23	West Aceh	809	12.05%	317	34.89%	391.84

Appendix 13 Plantation area in Aceh province (2004-2013)

	Municipal	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
1	Aceh Jaya	347	847	847	1,323	1,072	1,170	1,270	1,270	1,267	1,292
2	Aceh Singkil	398	440	444	565	315	496	540	585	636	640
3	Aceh Tamiang	681	831	976	851	2,065	2,470	2,604	2,610	2,215	2,031
4	Banda Aceh	0	0	-	-	0	-	-	-	-	-
5	Bener Meriah	134	134	174	237	237	737	750	933	1,190	1,053
6	Bireuen	2,773	2,773	2,845	2,925	2,943	4,600	4,741	5,436	6,023	6,671
7	Central Aceh	22	22	109	204	354	254	1,697	2,300	2,322	2,322
8	East Aceh	2,863	2,863	3,839	3,090	3,117	11,939	11,998	12,108	12,416	12,484
9	Gayo Lues	37	37	407	407	3,111	4,031	4,141	4,311	4,443	4,493
10	Greater Aceh	542	534	684	629	629	2,289	2,629	2,901	3,129	3,295
11	Langsa	225	225	225	220	202	200	272	287	303	301
12	Lhokseumawe	124	124	124	131	131	130	135	135	135	135
13	Nagan Raya	813	1,126	2,698	3,328	4,033	4,051	4,993	5,053	5,372	5,405
14	North Aceh	2,533	2,533	2,532	5,077	6,327	8,603	8,603	8,603	8,603	8,762
15	Pidie	8,906	8,981	9,230	10,537	5,495	8,247	8,247	9,464	9,599	10,150
16	Pidie Jaya	-	-	-	-	5,048	9,277	10,433	10,433	12,654	13,404
17	Sabang	638	701	638	638	638	638	637	637	637	737
18	Simeulue	945	945	727	1,264	1,565	1,606	1,870	1,890	1,806	1,598
19	Southeast Aceh	749	1,849	5,764	7,587	6,906	8,569	9,723	11,970	19,454	19,994
20	South Aceh	162	171	194	284	390	685	830	955	1,332	1,332
21	Southwest Aceh	1,299	1,404	1,404	1,758	4,259	4,096	4,356	4,356	4,356	4,300
22	Subulussalam	-	-	-	-	287	390	412	528	816	826
23	West Aceh	300	368	367	447	654	653	653	716	722	809

Appendix 14 Yearly cocoa production in Aceh province (2004-2013)

	Municipal	2004 [metric ton]	2005 [metric ton]	2006 [metric ton]	2007 [metric ton]	2008 [metric ton]	2009 [metric ton]	2010 [metric ton]	2011 [metric ton]	2012 [metric ton]	2013 [metric ton]
1	Aceh Jaya	119	104	106	106	106	260	112	210	206	159
2	Aceh Singkil	28	58	74	52	49	80	85	107	147	168
3	Aceh Tamiang	234	201	358	179	630	1,211	1,152	1,127	941	665
4	Banda Aceh	0	0	-	-	-	-	-	-	-	-
5	Bener Meriah	8	8	10	45	51	155	109	185	185	332
6	Bireuen	2,218	2,218	1,998	2,472	2,849	2,736	4,040	4,039	3,801	2,559
7	Central Aceh	2	2	4	4	22	36	253	455	546	786
8	East Aceh	2,254	1,974	1,578	1,593	1,599	6,808	6,972	6,881	6,536	6,684
9	Gayo Lues	16	16	20	45	400	363	363	660	888	902
10	Greater Aceh	52	182	182	183	183	195	277	277	426	426
11	Langsa	150	150	150	145	142	174	131	132	132	126
12	Lhokseumawe	42	42	42	59	59	55	64	59	64	65
13	Nagan Raya	237	194	569	569	570	1,343	1,415	1,331	1,335	1,327
14	North Aceh	1,268	1,268	1,179	2,268	3,412	2,692	2,680	3,056	2,730	3,222
15	Pidie	3,666	3,941	3,941	3,239	1,920	1,911	1,421	4,674	4,499	2,674
16	Pidie Jaya	-	-	-	-	1,779	1,946	2,362	2,795	3,619	4,349
17	Sabang	98	231	231	198	172	172	172	172	172	193
18	Simeulue	231	231	91	103	131	100	55	158	200	119
19	Southeast Aceh	232	960	3,503	4,578	4,227	5,230	6,230	7,622	8,843	8,843
20	South Aceh	18	22	28	28	28	70	85	106	153	169
21	Southwest Aceh	330	345	345	348	378	531	774	2,746	874	567
22	Subulussalam	-	-	-	-	52	92	108	108	130	143
23	West Aceh	66	48	45	78	228	306	327	350	235	317

Appendix 15 Cocoa production average in Aceh province (2004-2013)

	Municipal	2004 [kg/ha]	2005 [kg/ha]	2006 [kg/ha]	2007 [kg/ha]	2008 [kg/ha]	2009 [kg/ha]	2010 [kg/ha]	2011 [kg/ha]	2012 [kg/ha]	2013 [kg/ha]
1	Aceh Jaya	342.94	122.79	125.15	80.12	98.88	222.22	88.19	165.35	162.59	123.07
2	Aceh Singkil	70.35	131.82	166.67	92.04	155.56	161.29	157.41	182.91	231.13	262.50
3	Aceh Tamiang	343.61	241.88	366.80	210.34	305.08	490.28	442.40	431.80	424.83	327.42
4	Banda Aceh	-	-	-	-	-	-	-	-	-	-
5	Bener Meriah	59.70	59.70	57.47	189.87	215.19	210.31	145.33	198.29	155.46	315.29
6	Bireuen	799.86	799.86	702.28	845.13	968.06	594.78	852.14	743.01	631.08	383.60
7	Central Aceh	90.91	90.91	36.70	19.61	62.15	141.73	149.09	197.83	235.14	338.50
8	East Aceh	787.29	689.49	411.04	515.53	512.99	570.23	581.10	568.30	526.42	535.41
9	Gayo Lues	432.43	432.43	49.14	110.57	128.58	90.05	87.66	153.10	199.86	200.76
10	Greater Aceh	95.94	340.82	266.08	290.94	290.94	85.19	105.36	95.48	136.15	129.29
11	Langsa	666.67	666.67	666.67	659.09	702.97	870.00	481.62	459.93	435.64	418.60
12	Lhokseumawe	338.71	338.71	338.71	450.38	450.38	423.08	474.07	437.04	474.07	481.48
13	Nagan Raya	291.51	172.29	210.90	170.97	141.33	331.52	283.40	263.41	248.51	245.51
14	North Aceh	500.59	500.59	465.64	446.72	539.28	312.91	311.52	355.22	317.33	367.72
15	Pidie	411.63	438.82	426.98	307.39	349.41	231.72	172.31	493.87	468.69	263.45
16	Pidie Jaya	-	-	-	-	352.42	209.77	226.40	267.90	286.00	324.46
17	Sabang	153.61	329.53	362.07	310.34	269.59	269.59	270.02	270.02	270.02	261.87
18	Simeulue	244.44	244.44	125.17	81.49	83.71	62.27	29.41	83.60	110.74	74.47
19	Southeast Aceh	309.75	519.20	607.74	603.40	612.08	610.34	640.75	636.76	454.56	442.28
20	South Aceh	111.11	128.65	144.33	98.59	71.79	102.19	102.41	110.99	114.86	126.88
21	Southwest Aceh	254.04	245.73	245.73	197.95	88.75	129.64	177.69	630.39	200.64	131.86
22	Subulussalam	-	-	-	-	181.18	235.90	262.14	204.55	159.31	173.12
23	West Aceh	220.00	130.43	122.62	174.50	348.62	468.61	500.77	488.83	325.48	391.84

Appendix 16 Household income sources in Aceh (Nias as comparison)

Sources		Inland Area						Coastal Area					
		Pidie		West Aceh		Nias		Pidie		West Aceh		Nias	
No. of Respondents		39	families	44	families	40	families	35	families	39	families	38	families
Agriculture		74.9%		81.4%		80.9%		60.4%		89.2%		81.6%	
	Food Crops		14.9%		9.3%		1.4%		0.6%		3.2%		19.1%
	Cash Crops		57.1%		64.3%		78.2%		2.3%		59.2%		38.1%
	Fisheries		0.0%		0.0%		0.0%		56.9%		7.0%		9.3%
	Livestocks		2.9%		7.8%		1.3%		0.6%		19.8%		15.1%
Non-agriculture		25.0%		18.1%		17.2%		38.2%		10.7%		15.1%	
Others		0.1%		0.5%		1.9%		1.4%		0.1%		3.3%	
	Daysmen		0.1%		0.5%		0.0%		1.4%		0.1%		1.1%
	Government Assisted		0.0%		0.0%		1.9%		0.0%		0.0%		2.2%
TOTAL		100.0%		100.0%		100.0%		100.0%		100.0%		100.0%	

Appendix 17 Technological intervention being introduced first[2]

[2] the second intervention is posited as a hypothetical one