Bridging Islands and Calming Seas: A Material Flow Management Approach to Sustainable Sea Transportation for Fiji’s Lower Southern Lau Islands

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by

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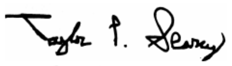
Sworn Declaration

I, Taylor Patrick Searcy (student ID 51214618), declare that this thesis entitled “Bridging islands and calming seas: A material flow management approach to sustainable sea transportation for Fiji’s lower southern Lau islands” and submitted for the degree of Master of Science in International Cooperation Policy (Sustainability Science) is my original work and research. Professor Yan Li is my supervisor who provided guidance and direction. All secondary data collected and used in this thesis are properly cited in accordance with American Psychological Association (APA) 6th Edition.



Taylor Patrick Searcy

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List of Abbreviations

ADO	Automatic diesel oil
BAU	Business as usual
CH_4	Methane
CO_2	Carbon dioxide
CO_{2e}	Carbon dioxide equivalent
COP	Conference of the Parties
DWT	Deadweight tonnage
EEDI	Energy efficiency design index
GDP	Gross domestic product
GHG	Greenhouse gas
GSFS	Government shipping franchise scheme
GSS	Government Shipping Services
HFO	Heavy fuel oil
IEA	International Energy Agency
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
MDO	Marine diesel oil
MEPC	Marine Environment Protection Committee
MFA	Material flow analysis
MFM	Material flow management
MoIT	Ministry of Infrastructure and Transport
MSAF	Maritime Safety Authority of Fiji

MWTPU	Ministry of Works, Transport, and Public Utilities
N_2O	Nitrous oxide
OCST	Oceania Centre for Sustainable Transport
OECD	Organization for Economic Cooperation and Development
PIC	Pacific island country
PIFS	Pacific Islands Forum Secretariat
SE4All	Sustainable energy for all
SIDS	Small island developing states
SME	Small-to-medium sized enterprise
SPC	Secretariat of the Pacific Community
SSI	Sustainable Shipping Initiative
TPU	Transport Planning Unit
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USP	University of the South Pacific
WTO	World Trade Organization

Glossary of Fijian Terms

camakau	outrigger sailing canoe
drua	large double-hulled sailingvessel
mataisau	craftsman, builder; shipwright clan
takia	small outrigger dugout canoe
temana o temoana	the spirit of the ocean
vesi	*Intsiabijuga* – hardwood used for hull construction
waqa	sacred

Maroroyanawasawasa, nawasawasa e namaroroiiko

"Care or look after the ocean, and the ocean will look after you"[1]

[1]Message of Fijian Islands Voyaging Society, signifying the need to use both ancient and modern ideas to preserve and sustain the ocean that provides abundance and life. Retrieved April 2016 from http://blog.imiloahawaii.org/general-information/uto-ni-yalo-fiji-islands-voyaging-society-canoe/.

Acknowledgements

As the mysterious plans of the universe reveal themselves, a serendipitous opportunity to study the remote Lau island of Fiji reinvigorated my buried interest in the vast Pacific Ocean. I am most grateful to Dr. Pete Nuttall, Ali Newell, and all the helpful staff at the University of the South Pacific who helped me to focus my research, thus enabling me to embark *MV Liahona* and experience the reality of sea transportation connecting these remote islands. It is from this short journey back in March 2015 that I have developed this research into my first Master's thesis. Much thanks goes to Jeke and the entire staff at the Transport Planning Unit as well as the hardworking crew of *MV Liahona*. To Peni, Ta, Na, and the whole family who graciously hosted me in Suva, *vinaka*. I hope to see you soon!

Furthermore, I must thank Dr. Yan Li at Ritsumeikan Asia Pacific University for her guidance and direction as my thesis advisor. Without her recommendation to find something that both excites my research interest and builds upon my experience in the Navy, I would have never begun looking into sustainable sea transport. Thank you for your dedication and sage advice. I owe a warm thanks to Professors Fellizar, Mahichi,Pishva and Chen in Beppu as well as Dr. Prof. Heck, Dr. Knaus and the IMAT team in Birkenfeld. Thank you for your guidance and patience.

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Abstract

The relatively remote and geographically isolated lower southern Lau islands of Fiji rely on maritime transportation for their economic success and social wellbeing. This thesis explores the feasibility of implementing a Material Flow Management (MFM) framework to sustainable shipping and the possibilities for ecological quality improvement and local added value. The research question is: **howcan a regional MFM framework for hybrid powered maritime vessels be implemented effectively to promote ecological quality improvements and local added value for Fiji's lower southern Lau islands?** The mixed methods research uses a quasi-experimental design, with most data collected on site during a March 2015 field study of the lower southern Lau route. The findings are applied to a tailor-made MFM framework that demonstrate the viability and effectiveness in achieving seven key aims: 1) activate regional potential; 2) increase system efficiency; 3) decrease operating costs; 4) create stakeholder network; 5) create and maintain jobs; 6) support innovative small and medium enterprises (SMEs); and 7) create sustainable economy/society. The results validate the MFM framework as a potential model of sustainable sea transport for small islands. Finally, the thesis concludes that further research that collects and analyzes more comprehensive data will be most beneficial to determining the full effectiveness of MFM as it applies to sustainable sea transport.

1 Bridging islands and calming seas

The sea is as real as you and I, it shapes the character of this planet, it is a major source of our sustenance, and it is something that we all share in common wherever we are in Oceania: these are all statements of fact. Above that level of everyday experience, the sea is our pathway to each other and to everyone else, the sea is our endless saga, the sea is our most powerful metaphor, the ocean in us.(EpeliHau’ofa, 1998, 43)

Renowned social anthropologist and Pacific islanderEpeliHau’ofasuccinctly museson the essential aspect of human development on Earth: *the ocean in us*. Indeed, of all the various forces that have shaped humanity, the ocean can be considered the most influential – providing everything from sustenance and conveyance to countless sagas of cultural and religious significance. The water that gives our planet its blue hue is the critical element of life on the only known inhabitable planet in our solar system. With this gift of life, humans have been endowed with the powers of intellectual curiosity, reason, and ingenuity – arguably above all other life forms inhabiting this blue planet. Together, these two gifts of the resource-rich seas and life as a human come with profound responsibility to our collective existence.

Going back to the ancient Sanskrit epic *Mahabharata*, the well-known *Bhagavad Gita* imparts this wisdom of selfless service (i.e., *Karma yoga*) that is central to our responsibility as inhabitants of this beautiful planet. In this saga, the sage Lord Krishna advises Arjuna, “you also should perform your duty with a view to guide people and for the universal welfare of society”(Prasad, 2013, 48). Modernity and all that it entails – uncontrolled resource consumption, rapid transportation, instant gratification, etc. – has eviscerated this idea of the duty of human existence so eloquently elucidated in the *Bhagavad Gita*. Now that the myriad unintended consequences of industrialization are blaringly apparent, we must change our collective habits to safeguard our planet for future generations (WWF, 2014, 5). The economic, political, and social systems that have led to truly remarkable feats of human ingenuity and brought about drastic improvements to our daily lives have also created problems of unwieldy magnitudes. However, the growing movement across the globe for the peaceful and sustainable development of humanity provides a glimmer of hope for future wellbeing.

In this vein lies the foundation of this thesis. Each and every small effort to examine an issue in depth to enrich our collective understanding and provide improvements for humanity and the natural world is well worth the endeavor. Going back to EpeliHau'ofa, this thesis explores one small yet important aspect of the sea that shapes our planet: sea transportation. The topic is narrowed down into one specific case study of a small route in the remote islands of eastern Fiji, thus providing a baseline scenario to explore sustainable methods of sea transportation. The remaining sections of this introduction provide a general overview of the specific issues to discuss as follows: 1.1) sea transportation and the environment; 1.2) the role of sea transportation in Oceania; 1.3) Fiji's lower southern Lau islands; 1.4) Material Flow Management approach to sustainable development.

1.1 Sea transport and the environment

Sea trade is inextricably linked with the global economy. This association between economic growth and industrial activity with trade clearly indicates the expansive nature of maritime transport services (UNCTAD, 2015, 5). In fact, shipping accounts for over 90% of global trade (IMO, 2011, 2). Thus, sea trade is paramount to the growth of the global economy. Without oversimplifying these connections, it is important to grasp the magnitude of these links. The growing demand for an already huge shipping industry in transporting goods around the world clearly requires a growing use of fossil fuels.

This aspect is key to understanding the basis of this thesis; as global trade increases, the demand of shipping services increases, and ultimately the amount of finite fossil fuels that pollute the oceans and atmosphere likewise increases (see sections 2.1 and 2.2). The principle regulatory authority for all matters regarding shipping is the International Maritime Organization (IMO), a behemoth agency under the umbrella of the United Nations. In the most recent United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) – known as COP21 or the Paris Agreement – key organizations (e.g., Sustainable Shipping Initiative – SSI) and leading individuals (e.g., Foreign Minister Tony de Brum of the Republic of the Marshall Islands) called for action on part of the IMO to set limits to greenhouse gas (GHG) emissions from shipping (SSI, 2015). To date, the IMO has been reluctant to make any stringent limits – or any limits at all; in fact, the IMO along with its sister organization for aviation the International Civil Aviation Organization (ICAO) remain outside the scope of UNFCCC GHG emissions limits since the Kyoto Protocol (Smith, 2016).

With the visible trend of a global path towards sustainable development, sea transportation will play a significant role. As economic growth is becoming decoupled from environmental impacts such as GHG emissions, sustainable shipping options must be included. The shipping industry is considering various approaches to a sustainable shipping future, ranging from greater fuel efficiency and renewable energy technologies to improved operational and logistical coordination (see section 2.3). This thesis delves into a specific scenario of a small yet scalable model to improve sea transportation among small islands. As such, the following sections introduce the location and framework that compose this thesis.

1.2 Oceania: A sea of islands

As part of the extensive geopolitical area known as Oceania, the Pacific Island region consists of over 7,500 islands (of which only around 500 are inhabited) comprising 22 island countries covering a 30 million square kilometer area of the Pacific Ocean (Haberkorn, 2008, 97). This region, containing just 0.1 percent of the world's population, sits on the periphery of global development initiatives.In fact, most geographers and cartographers conceptualize the world as a division of continents – remote Oceania as a "continent" in its own right became common only as late as the early 20th century (Lewis and Wigen, 1997, 31). Without delving into historical, geopolitical and cartographical imperatives, Oceania must be considered a region in its own right; it is a "sea of islands" full of diverse populations, natural resources, and the vast ocean that connects it all.[2]

The significance of the notion of Oceania as a sea of islands provides the context for the geographical setting of this thesis. If any small-scale sustainable shipping initiatives are to be tested and implemented, the Pacific Island Countries (PICs) are ideal choices. One of the most critical aspect of effective socio-economic development in this region hinges upon a regionally integrated, sustainable maritime transportation sector. Maritime transportation is the lifeline of trade and economic development for PICs, and the recent advances in low-carbon technologies and sustainable shipping innovations (e.g., OCIUS; Greenheart Project) highlight the growing interest in this field of study (Nuttall, 2014). The common features of maritime transportation in this region – geographic remoteness, limited volumes of trade, a heavy dependence on imports, and low volumes of a few key exports (UNCTAD, 2014, 106) – provide an opportunity to develop different renewable energy technologies for marine transportation.

[2] See EpeliHau'ofa's essay "Our sea of islands" in E. Waddell, V. Naidu and E.Hau'ofa (eds), *A New Oceania: rediscovering our sea of islands*. Suva: USP. 2–16.

A slow but steady growth of academic interest in this subject is evident from the Sustainable Sea Transport Talanoa 2012; this provided the impetus for Oceania to become the center for developing sustainable sea transport options (Nuttall et al, 2014, 283). Under the guidance of Dr. Peter Nuttall, the leading expert on this subject and head of the Oceania Centre for Sustainable Transport (OCST) at the University of the South Pacific (USP) in Laucala, Fiji, the opportunity to focus on domestic shipping in Fiji presented itself as an apt and meaningful option in which to conduct this research. Specifically, the most uneconomical route for Fiji's government: the monthly trip to the lower southern Lau islands. This particular case study is the centerpiece of the research in this thesis and is used as a model for domestic and regional shipping routes in Oceania.

1.3 Fiji and the lower southern Lau islands

Of all PICs, Fiji is most suitable as a location for this case study. As mentioned in section 1.2, Fiji has an established research program on this subject.[3] Out of the 10 PICs that are member countries of the World Bank, Fiji has both the largest population (886,500 inhabitants) and highest Gross Domestic Product (GDP) at US$4.532 billion (World Bank, 2016). Furthermore, Fiji is a major center for international and regional organizations, including the International Union for Conservation of Nature (IUCN) Oceania office, the United Nations Development Programme (UNDP) regional office, Pacific Islands Forum Secretariat (PIFS), and the Fiji regional office of the Secretariat of the Pacific Community (SPC). SeeFigure 1.1for a map of Fiji.

[3] For a thorough understanding of Fiji as a central location for such research, see *Sustainable sea transport research program: Toward a research-based programme of investigation for Oceania* (Prasad, B. et al., 2013; *The journal of Pacific studies*, 33:1, 2013).

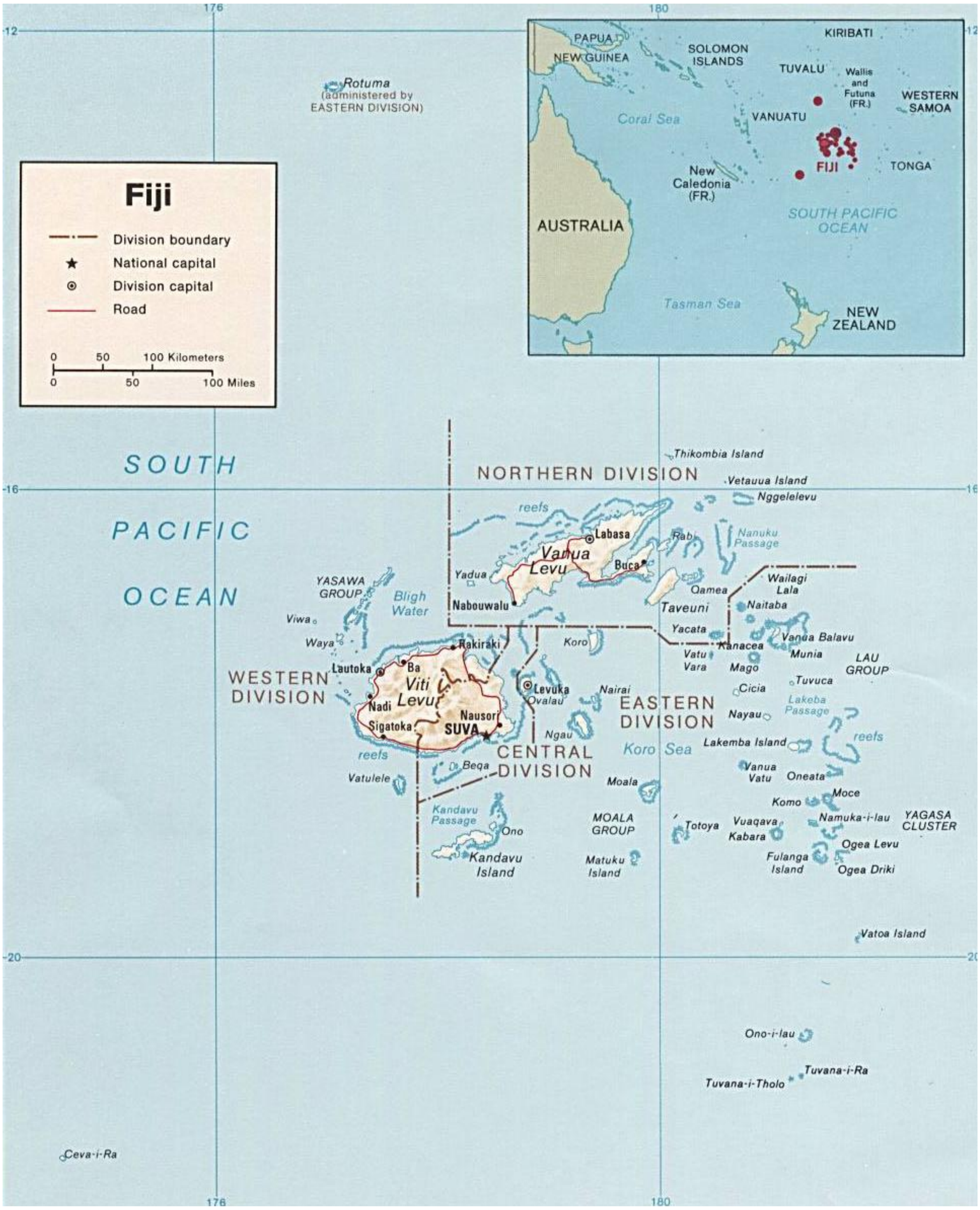

Figure 1.1: Map of Fiji (Source: Fiji Bureau of Statistics, 2014)

The next question that arises is: why research the lower southern Lau islands? In order to focus the scope of this research, and based onofficial statements from the Ministry of

Infrastructure and Transport (MoIT)[4], the most uneconomical domestic shipping route for the Fijian government is the lower southern Lau route (MWTPU, 2014). Figure 1.2 shows a map of the specific route to the five lower southern Lau islands of Kabara, Fulaga, Ogea, Vatoa, and Ono-i-Lau. Thus, this inter-island shipping route provides a challenging yet applicable case study into sustainable shipping solutions. For more information, Chapter 5provides the relevant data and results regarding this route in particular.

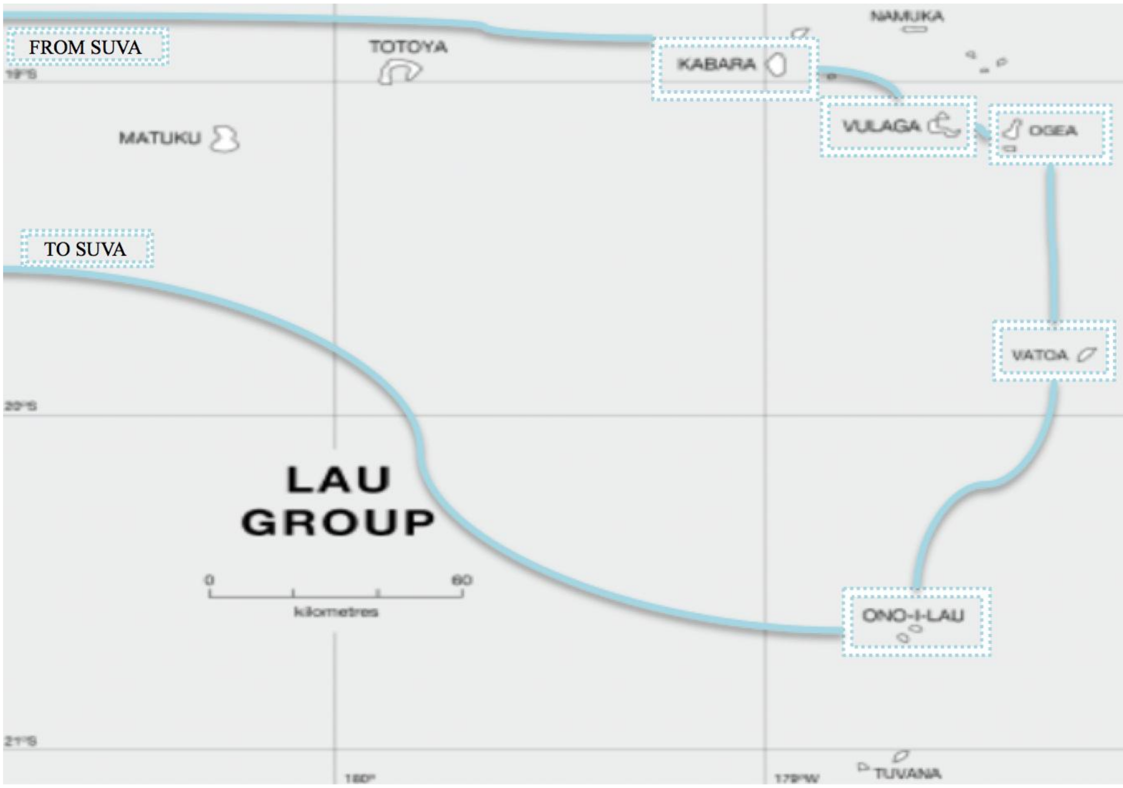

Figure 1.2: Lower southern Lau islands shipping route (Source: Author's edition)

1.4 Material flow management (MFM) approach to sustainable development

This master's thesis proposes a Material flow management (MFM) model to improve the effectiveness and efficiency of the shipping route to Fiji's lower southern Lau islands. What, then, is MFM, and what attributes make it suitable for sustainable shipping among

[4] Ministry of Infrastructure and Transport (MoIT) formerly known as Ministry of Works, Transport, and Public Utilities (MWTPU). To remain consistent, this thesis uses the most current name – MoIT.

Pacific island countries? MFM is a specific technique to interlink the technical-economic approach of optimization to ecological value (Enzler, 2006). This consists of a value-added network of both direct and indirect stakeholders. The necessity of utilizing environmental accounting instruments in the MFM approach demonstrates the effectiveness of various tools and concepts that effectively improve the economic and environmental situation (Lang-Koetz et al., 2006).

One of the most critical aspects of MFM is the concept of local and regional added value, which Heck, Baur, Frorath, and Koch (2005) define as, "the benefits which can be achieved by activating own local or regional sources of food, energy or material supply and so on." Thus, material, energy, and financing – among other factors – all must be optimized at the smallest level possible in order to deliver the most effective local or regional added value (see Chapter 4 for more information). Most MFM studies have focused on land-based renewable energy systems such as wind turbines, biogas generation, and waste management; in contrast, this research will explore the benefits of MFM to maritime transportation.

By applying the MFM approach of sustainable development to domestic shipping of Fiji's lower southern Lau islands, this thesis offers a model to help bridge islands and calm the tumultuous seas of anthropogenic climate change and environmental degradation throughout the Pacific.

2 The case for sustainable sea transport

A growing body of research is being conducted across nearly all sectors of human activity to examine anthropogenic environmental problems. Sea transportation is one such sector that is gaining momentum in the drive to reduce GHG emissions and other pollutants generated by mankind. The literature review focuses on three primary aspects most relevant to this research: 1) shipping as it relates to social and economic activity; 2) the impact of shipping on the environment; and 3) sustainable sea transport options. These sections are further divided into subsections that review applicable literature, providingthe most succinct synopsis of the information pertinent to the research presented here.

2.1 Shipping: The backbone of economic activity and a globalized society

The highly mobilized, interconnected infrastructure that is the hallmark of 21st century economic activity is largely dependent on sea trade. The *2015 Review of Maritime Transport* highlights this fact, as global economic growth drives up the demand for maritime transport services and its trade volumes (UNCTAD, 2015, 5). The estimates provided indicate a 3.4 percent expansion of seaborne merchandise shipments in 2014; this is equivalent to an additional 300 million tons, bringing the total volume to 9.84 billion tons, or approximately 80 percent of the world total in merchandise trade (UNCTAD, 2015, 5).Figure 2.1 shows the association between these trade estimates and industrial activity based on data from the Organization for Economic Cooperation and Development (OECD), World Trade Organization (WTO), and other statistical sources. An important aspect of this trend, however, is that the share of world merchandise trade from developed countries is declining and that of developing countries is on the rise (45.0 percent of world exports and 42.2 percent of world imports in 2014) (UNCTAD, 2015, 3). Most PICs are under the latter category.

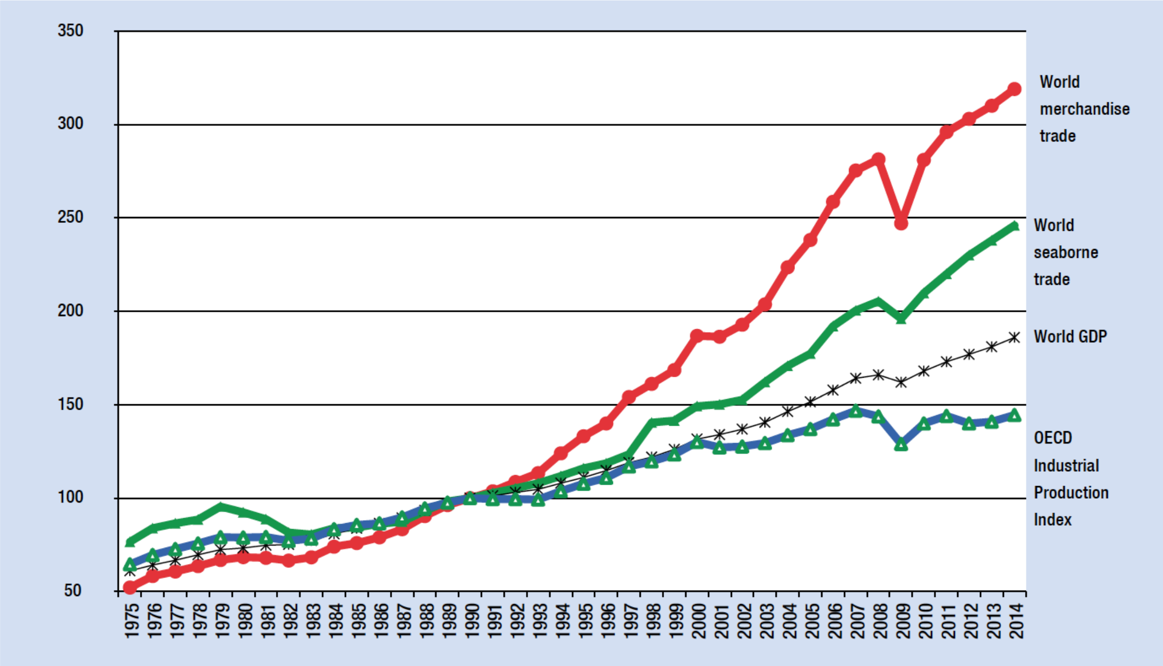

Figure 2.1: Economic growth, industrial activity, and trade[5] (Source: UNCTAD, 2015, 5)

Shipping is not only the lifeblood of the global economy, it is also considered to be a barometer of world trade; along with the growth of economic activity in recent decades, ton-miles of cargo have doubled from 1990 to 2008 (SSI, 2011, 12).Dr. Martin Stopford provides an excellent assessment of historical trends in shipping in his 2010 speech “How shipping has changed the world & the social impact of shipping”. In his speech, he reviews the importance of shipping over the past 5000 years and highlights the critical mass to globalization that shipping has become now that it is “hooked on oil” (Stopford, 2010). The fact remains that shipping is central to our globalized economy, and as such, it shapes the modern society and lifestyle of mass consumption with intractable force.

2.1.1 Sea transportationin Oceania

Oceania, a vast geographical region encompassing the conceptual divides of Polynesia, Micronesia, and Melanesia, is truly remarkable in that it is the only “continent”

[5] Estimates provided by OECD Industrial Production Index, world GDP index, and both merchandise trade and seaborne shipment indices from 1975 to 2014 (base year 1990 = 100)

characterized by numerable small islands and archipelagos (i.e., limited land) and a truly immense expanse of ocean. Historian Paul D'Arcy, in his pivotal book *People of the sea: Environment, identity, and history in Oceania* (2006), provides a comprehensive investigation on the role of the sea in Oceanic cultures. In this, D'Arcy underscores the importance of including all aspects of the sea – from maritime activities to ocean ecosystems, for the sea is a dominant aspect in the thoughts and actions of Pacific islanders (D'Arcy, 2006, 169). Throughout the book, he depicts the shifting ambitions and varying connectivity across both small and large spaces of the ocean. The changing influence of sea voyages, societal developments, and the intrusion of Western cultures all provoked the transformation away from the seafaring culture that once played such a pivotal role in the societies of Pacific islanders.

Figure 2.2: ***Temana o temoana*****arrival in Suva, Fiji (June 2012)** (Source: Pacific Voyagers, 2012)

The name "Oceania" itself conveys the heart of this expansive part of Earth. Sea-going vessels, being the pinnacle of social and cultural achievement, required the most time and resources from the indigenous communities (Nuttall, D'Arcy, &Philps, 2014, 3). This seafaring heritage has been in decline over the past century due to a variety of factors, such as developments in transportation, telecommunications and cultural influences (D'Arcy, 2006; Nuttall, 2010; Nuttall, Newell, Prasad, Veitayaki, & Holland, 2014; Moon, 2013). However, a recent revival in this heritage is taking shape, evidenced by the growth in Pacific island voyaging societies, the 2011 *Temana o temoana* ('The spirit of the ocean'), and the 2012 Festival of Pacific Arts (Pacific Voyagers, 2012). This forward momentum, together with significant effort from engaged and passionate individuals, led to the successful Sustainable Sea Transport Talanoa in November 2012 (Nuttall, 2013, 254). Now more than ever, this cultural and social resurgence in seafaring heritage together with the economic and environmental priorities of the times offer an exceptional opportunity to further the developments of sustainable sea transportation in Oceania.

2.1.2 Significance of sea transportation in Fiji

As the "hub of the Pacific", Fiji is an important center for international shipping services, telecommunication and regional business activity (Investment Fiji, 2010). Fiji has a long and storied history with its seafaring prowess. Most notable is the "finest two-hulled sailing vessels built by Pacific islanders" – the magnificent *drua*, a shunting vessel over 100 feet long, 200+ passenger capability, and up to 15 knots (Nuttall et al., 2012). Figure 2.2 below shows one of the last remaining*waqadrua*, housed at the Fiji Museum in Suva. While the *drua* is the most emblematic symbol of Fiji's sailing heritage, other noteworthy vessels such as the*camakau*were more prevalent throughout the islands.

Figure 2.3: *RatuFinau* - the last *waqadrua* (Source: Author's photograph, March 2015, Fiji Museum)

As Nuttall, D'Arcy and Philps(2014, 2) indicate, historical analyses and perspectives on Fijian sailing culture are dispersed among various sources. One of the most detailed accounts of Lau culture comes from Laura Thompson (1938; 1949). The Lau islands of Kabara, Fulaga and Ogea are unique in their limestone foundations, and they have traditionally been the source of hardwoods ideal for shipbuilding (*Intsiabijuga* [6], *Pittosprumbrackenridgei*, *Dysoxylumrichii*). Rich in resources and geographically closer to Tonga, the Lau islanders have strong historical and cultural ties with Tongan society. Due to this, the Lau island of Kabara became a strategic and influential island in the South Pacific (Banack and Cox, 1987, 148). An excellent reference of more recent times is *Traditional sailing canoes in Lao* (*Na camakaumainayatu Lau)* (Gillett et al., 1993).

2.2 Environmental impacts of shipping

Transporting good across the world's oceans takes it's toll on the environment. Both atmospheric composition and marine ecosystems – coral reefs, coastal habitats, etc. – are

[6] Known as *vesi* in Fiji, *Intsiabijuga* is the most valuable resource of Kabara. It is resistant to insect and water damage, and is the primary timber used for *drua*hulls. (Banack and Cox, 1987, 149).

faced with an increasing threat to their natural balance. This thesis focuses on GHG emissions, but other environmental impacts are discussed as well. The following two subsections review the latest studies on emissions from shipping and other notable impacts on the environment.

2.2.1 Shipping and GHG emissions

With the release of the Intergovernmental Panel on Climate Change (IPCC) report entitled *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, a growing consensus among scientists and policymakers alike indicates the imperative need for reducing the global carbon footprint of humanity. Shipping only presents a small contribution to global greenhouse gas (GHG) emissions, (approximately 2.8% annually from 2007-2012), yet it is clearly the backbone of globalization and economic development (IMO, 2014, 13; IMO, 2011; UNCTAD, 2014). For a country comparison, the share of CO_2 emissions from Germany – the world's sixth largest emitter – is 2.2% (Olivier, Janssens-Maenhout, Muntean, & Peters, 2015).

According to the latest report from the International Energy Agency (IEA), transportation accounts for nearly one-quarter of all global CO_2 emission[7] (IEA, 2015, 10). Figure 2.4 shows this breakdown. Of particular note, emissions from marine bunkers were 64 percent higher in 2013 than in 1990, nearly on par with the 68 percent increase in emissions from road transport over the same period (IEA, 2015, 11). The growth in trade is a major factor in this emissions increase, but perhaps most surprising is the deterioration in efficiency since the 1990s partly caused by lower design quality (Faber &Hoen, 2015, 7).

[7] CO_2 accounts for the majority of GHG emissions from shipping. In 2012, CO_2 emissions from shipping were approximately 949 million tons, while those of carbon dioxide equivalents (CO_{2e}) – including CO_2, methane (CH_4), and nitrous oxide (N_2O) – were approximately 972 million tons (IMO, 2014, 74). As such, this thesis focuses on CO_2 as the principle GHG.

As the IMO likes to emphasize, in terms of volume-distance (ton-miles), international shipping is considered the “most efficient, safe and environmentally friendly mode of transporting goods around the world” (IMO, 2011). However, the IMO’s own Marine Environment Protection Committee (MEPC) projects an increase of CO_2emissions between 50 and 250 percent for all business as usual (BAU) scenarios (IMO, 2014, 34). Even with improvements in energy efficiency and emissions reductions, all but one of the future scenarios result in higher emissions in 2050 than in 2012 (IMO, 2014, 34)(Figure 2.5). Delaying implementation of emissions regulation for international shipping is the single biggest risk to the future of shipping and world trade, for it increases the rate at which the industry must change (Smith &Rehmatulla, 2015, 2).

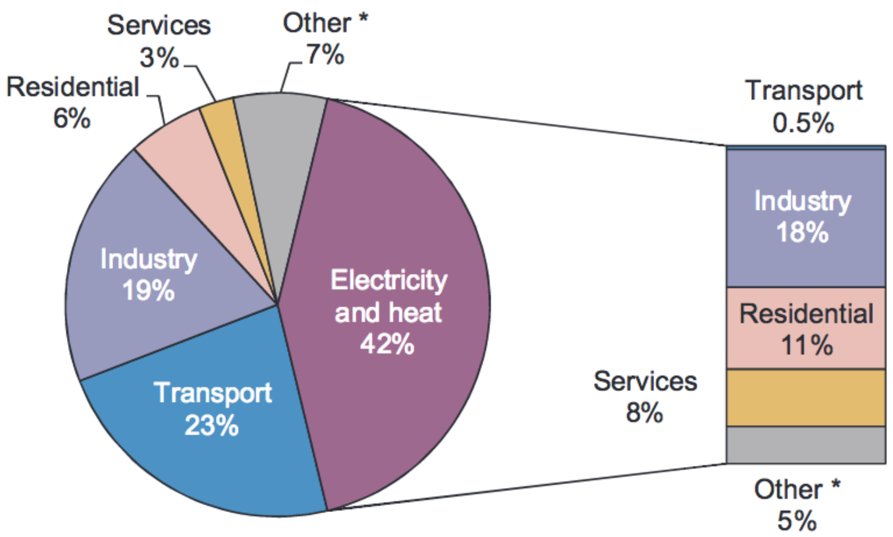

Figure 2.4: World CO_2 emissions by sector in 2013 (Source: IEA, 2015, 10)

Since the scope of this thesis is limited to a single shipping route in Fiji, a further background analysis of relevant data is required. First, when examining marine transport emissions, domestic shipping contributes much less to the overall total. Using the bottom-up method of emissions calculations as determined by MEPC, total CO_2 emissions from shipping were 949.1 million tons in 2012, of which 131.4 million tons are attributed to domestic navigation (compared with international shipping – 795.7 million tons and fishing – 22.0 million tons) (IMO, 2014, 24). At the micro level of fuel consumption, baseline CO_2 emissions are anywhere from 2.75 to 3.206 grams CO_2 per gram fuel (IMO, 2014, 42). Furthermore, the trend of newer and larger vessels results in greater efficiency and lower emissions per ton-mile (Buhaug et al., 2009, 63). However, older and smaller vessels dominate domestic shipping in Fiji – and Oceania in general. This means that the vessels used in Fiji's domestic shipping disproportionately account for GHG emissions and other environmental problems. Domestic shipping in PICs tends to be overlooked or disregarded when it comes to efficiency improvements, emissions reductions and economies-of-scale (Nuttall, 2013).

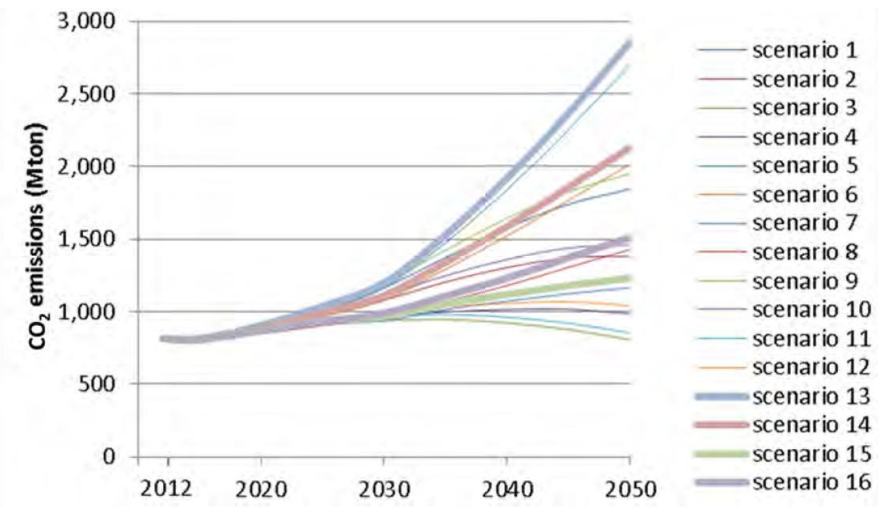

Figure 2.5: CO_2 emissions projections for international sea transport (Source: IMO, 2014, 34)

2.2.2 Other environmental impacts of shipping

Aside from GHG emissions and its effect on global climate change, shipping causes a host of other environmental problems. Major concerns directly and indirectly linked to GHG emissions are ocean acidification, rising average atmospheric and ocean temperatures, and the related impacts to biodiversity and the ocean ecosystems (IMO 2011; Broadgate et al., 2013; IPCC, 2014; WWF, 2014). Other significant examples of environmental impacts from shipping include:1) the transfer of aquatic species in ballast water systems, oil spills, and dumping of waste – all negatively altering marine ecosystems; and 2) ship recycling (i.e., 'shipbreaking') – a toxic hazard to both public health coastal habitats (IMO, 2011). These various environmental problems require critical, timely solutions in their own right. However, they are outside of the scope of this thesis, and will only be considered as secondary benefits to a MFM approach to sustainable shipping in the lower southern Lau islands.

2.3 Sustainable sea transport options

The growing academic, economic, and cultural interest in sustainable sea transport is evident in the historical trends of the past 40-50 years. Not surprisingly, economic factors are the catalyst for positive change; in this case, the late 1970s oil crisis and subsequent fossil fuel price increases drove research and development into more efficient, cost-saving technologies (Nuttall, Newell, Prasad, Veitayaki, & Holland, 2014; Nuttall, 2010). A case in point is the *Tai Kabara*(Figure 2.6), a Lau-built, owned, and operated wind-powered vessel servicing the southern Lau islands from the 1980s to 2000s (Nuttall,Ledua, Newell, Vunaki, &Philps, 2012, 19). This is a prime example of the opportunities, challenges, and needs of this thesis, for it is a recent scenario pertinent to the lower southern Lau islands.

Another economic factor is the profit maximizing behavior of ship operators (Moon, 2013, 8). Islands with inadequate port infrastructure or economic value are further marginalized, leading to a circular problem of underdevelopment. Now that the global community of scientists, policy makers, and private organizations are aware of the reality of climate change, the need for serious commitment to research and development from all angles – economic, environmental, social, finance and policy – can not be overstated. The following subsections review three broad categories of research in sustainable shipping practices: technological improvements, operations/logistics management, and economic policy mechanisms.

Figure 2.6: *Tai Kabara*, wind-powered vessel servicing southern Lau islands, 1980s-2000s (Source: Nuttall et al., 2012, 19)

2.3.1 Technological improvements

The latest trends of performance efficiencies and larger vessel size (e.g., Maersk's Triple E class) support the idea that economies-of-scale can meet the growing demands of shipping while reducing GHG emissions. Lindstad, Asbjørnslett and Strømman (2012) provide an empirical study that by replacing the existing merchant fleet with larger vessels, emissions can be reduced by up to 30%. Alternatively, a study by Glykas, Papaioannou and Perissakis (2010) shows that the payback period of solar-hybrid power systems in shipping, based on various fuel price increases, is a minimum of 10 years. Many of these developments are to meet the criteria of the IMO-mandated Energy Efficiency Design Index (EEDI). Approved by the IMO in 2011, this is the first globally binding climate change standard for sea transport (Transport & Environment, 2016). The rapid pace of development in renewable energy technologies in application to smaller merchant vessels promises to provide viable alternatives to shipping for SIDS (Teeter & Cleary, 2014).

2.3.2 Operations and logistical management

Several studies focus on a second method to reduce GHG emissions: through well-managed operational and logistical practices. The stochastic analysis of Qi and Song (2012) provides valuable data that indicates improved management of port-related uncertainty and vessel routing can contribute to minimizing fuel consumption and carbon emissions. Reduced speed – or slow steaming – is another operational practice that has the potential to reduce GHG emissions (Lindstad, Asbjørnslett&Strømman, 2011), but this strategy is only economically effective when considering the specific break-even bunker price (Cariou, 2011).

2.3.3 Economic and financial policy mechanisms

The third strategy worth mentioning consists of policy instruments and market-based incentives. Chang (2012) determined that emissions from shipping are more closely related to marine energy consumption than to GDP; thus, both the technological and operational aspects of shipping practices as well as economic growth scenarios are important factors to consider in developing sustainable sea transport models. The application of incentives for bio-diesel use (Lin, 2013), foregoing CO_2 apportionment schemes in order to establish a more effective, sub-global policy (Gilbert & Bows, 2012), and the challenges of policies ranging from Emissions Control Areas (ECAs) to emissions tax (Keen, Parry & Strand, 2013) have all been researched in an effort to determine the best policy measures to reduce GHG emissions in an economically viable manner. Likewise, Lai, Lun, Wong, & Cheng (2011) proposed a conceptual framework to evaluate green shipping practices that various shipping firms have been implementing. This research will follow a similar path of evaluating current innovations in shipping as they apply to the Pacific island countries in order to develop an MFM framework for sustainable shipping.

2.4 Sustainable shipping in Oceania: Challenges and opportunities

In 2014 – the International Year of Small Island Developing States (SIDS) – the United Nations Environmental Program (UNEP) emphasized the fact that SIDS contribute less than one percent to global GHG emissions, yet they are some of the most vulnerable communities to the impacts of climate change (UNEP, 2014, 4). This high vulnerability to environmental, economic and social systems is due to five intrinsic characteristics of SIDS (Moon, 2013, 1):

a) Small size
b) Remoteness
c) Vulnerability to external (demand and supply-side) shocks
d) Narrow resource base
e) Exposure to global environmental challenges

One of the most significant challenges that SIDS face is their high dependence on imported fossil fuels; as much as 95% is imported, of which up to an estimated 75% is used for sea transport (UNEP, 2014, 19; Woodruff, 2007; Mayhew, 2011). Due to the high vulnerability of PICs to external influences, all PICs excluding the territory of American Samoa run a trade deficit (Secretariat of the Pacific Community, 2014). Specific to sea transport, on average between 40 and 60 percent of total ship operating costs go towards fuel consumption (Nuttall, 2013, 258). This is yet another indicator of the potential viability of sustainable shipping options.

Characterized by unique features such as long routes, minute economies, and high infrastructural costs, to name but a few, shipping in Pacific island countries presents a tremendous challenge to long-term, sustainable sea transport (Nuttall, 2014). The physical and economic security of SIDS is highly vulnerable to the growing risks associated with global environmental change and economic liberalization (Pelling&Uitto, 2001), yet the nature of scientific inquiry and associated uncertainties have led to impediments to planning and adaptation (Barnett, 2001). Mishra, Sharma and Smyth (2009) provide various models for determining energy consumption and policy-making for the region, showing that energy consumption of Pacific island countries is significantly affected by structural breaks in world energy markets. The livelihood of Pacific islanders is dependent on external factors such as the global price of oil – especially considering their dependence on sea trade, thus the maritime transportation sector has tremendous potential to benefit from sustainable shipping practices (Nuttall, 2013; Nuttall, Newell, Prasad, Veitayaki, & Holland, 2014; Newell, Nuttall, Holland, Veitayaki& Prasad, 2014).

Stemming from increased research and scientific inquiry, the growing awareness of the need for urgent adaptation to climate change has led to many recent developments in policy instruments and sustainable shipping innovations. Commonalities of small island territories led to the development of economic models in relation to their positions vis-à-vis leading economies of the globalized world, but in practice small island territories are better served with policies that comprise a strategic mix of options (Baldacchino, 2006). Holland et al. (2014) estimated the impact of reduced carbon emissions from five prioritized policy areas specific to the region, which delineates the compromising choices that Pacific island countries must make. Renewable energy technologies – together with improved policies and funding strategies – are urgent priorities for the development of sustainable shipping in the Pacific (Nuttall, Newell, Bola, Kaitu'u& Prasad, 2014).

3 Theoretical foundation and MFM framework

The foundation of this thesis stems from the view that every aspect of human life on this planet causes unintended consequences on our surroundings; not only it is our duty to understand these complex cause-and-effect interactions through rigorous research, but also to develop and adopt the appropriate solutions best aligned to the natural processes of the world. This is accomplished through dedicated research. Thus, despite the assertion that shipping is the most efficient and environmentally-friendly mode of transportation (see section 2.2.1, paragraph 2), this thesisshows that improvements are possible and necessary to the implementation of a more sustainable sea transportation at the smallest level.

This thesis aims to contribute to the growing body of research regarding renewable energy technologies in their application to the maritime transportation sector. Specifically, it examines the application of the latest sustainable shipping developments as they pertain to smaller vessels in the context of a regional MFM framework for Fiji's lower southern Lau islands. This chapter is divided into six sections: 3.1) theoretical background; 3.2) MFM framework;3.3) research questions; 3.4) hypotheses; 3.5) research objectives; and3.6) significance of study.

3.1 Theoretical background

The title of this thesis includes the term *revitalizing*. Why chose this word, above all others? The answer lies in the fact that the lower southern Lau islands – particularly Kabara, home of renowned *mataisau* (craftsman, builder; shipwright clan) – were regional centers of excellence in terms of shipbuilding and construction, not to mention being blessed with the essential natural resources vital to this endeavor (see section 2.1.2: Significance of sea transportation in Fiji). Considering the historical records and the social, economic, and technological advances of the 21st century, the present difficulties of sea transport to these islands are confounding. This surely warrants revitalization in sea trade for the region. The theoretical basis of this study centers on the idea that the technical knowledge and seafaring prowess of Pacific islanders is not lost to history; to the contrary, the surviving *mataisau*have a strong desire to revitalize this living heritage before it is too late (Nuttall, Ledua, Newell, Vunaki&Philps, 2012, 13).

Additionally, the most recent research-in-progress on environmental Kuznet's curve and environmental convergence regarding CO_2 emissions shows that the positive relationship between economic growth and environmental degradation (i.e., CO_2 emissions)does not actually reach a turning point, making the case that the current development process is less environmentally sustainable than previously considered (Martino & Nguyen-Van, 2016). Thus, this research is important to research and identify a truly sustainable method that can be replicated throughout the region. Why must the Lau islanders continue to rely on fossil fuel based vessels that are past their serviceable lifetime (see Section 2.2.1, paragraph 3)? The shift from an admirable shipwright and seafaring heritage to unreliable dependence on dirty transportation does not have to be permanent, nor does it have to continue this way. In fact, by applying clean, efficient technologies with innovative financing and smart management, a shift towards clean sea transport is possible.

An important note must be included here as central to the theoretical background. Historians, anthropologists, and other social scientists have differing opinions over the efficacy of development. Does external development aid, or support given with egalitarian aims from external actors provide the best form of sustainable development? Or rather, dies this external drive seldom produce effective solutionsto address the root issue?[8] This thesis follows the belief that the best solutions to any problem of this sort come from within; in this vein, this thesis offers recommendations for possible solutions; the *right* solution for a sustainable sea transport system within the lower southern Lau islands, Fiji, or Oceania must come from the stakeholder within the system – the islanders, chiefs, government officials, ship owners, shipping operators, etc.

In sum, this thesis joins together the provenshipwright and seafaring heritage of the Lau islanders and the opportunities of modern renewable energy technologies in an effort to revitalize sea trade in the region.

3.2 MFM framework

The underlying theoretical framework of this thesis is the concept of Material Flow Management (MFM), (see MFM introduction in section 1.4). The basic idea is that with the application of more energy efficient technologies and other green business potentials, Fiji can effectively achieve sustainable shipping solutions (see Figure 3.1).

The MFM framework is one particular concept of sustainable development that is used extensively in Germany. Over two decades ago the German government promoted MFM as a "goal-oriented, responsible, integrated and efficient influencing of material systems. […] The goals are given by ecological and economical areas and by observing social aspects" (Heck, 2014, 23). As mentioned in sections 1.4 and 4.1, one central pillar of MFM is the concept of local or regional added value. This thesis suggests that the MFM model for German villages can be adapted to the idea of sustainable inter-island shipping

[8] For a recent and extensive review of the many facets, thoughts, and theories on development, see Peet, R. and Hartwick, E. (2015). *Theories of development: Contentions, arguments, alternatives*. New York: The Guilford Press. 3rd edition.

in Fiji. Indeed, as a proven concept in sustainable development projects around the world, MFM has great potential for success in this particular case.

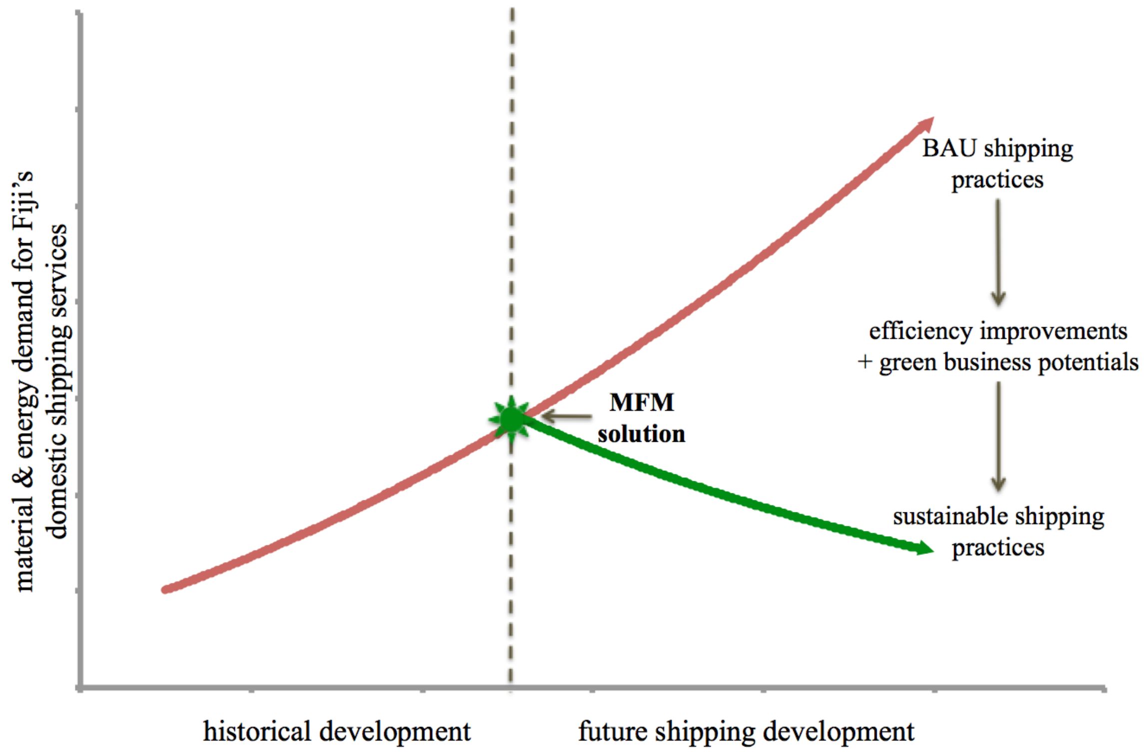

Figure 3.1: Material Flow Management for sustainable shipping

(Source: Author's adaptation of MFM model as described in Heck, 2014, 21)

3.3 Research question

This thesis presents a new, unique perspective on the concept of sustainable inter-island sea transport. The MFM framework described above is central to the main research question and subsidiary questions necessary to developing and testing the hypotheses.

3.3.1 Main research question

- How can a regional MFM framework for hybrid powered maritime vessels be implemented effectively to promote ecological quality improvements and local added value for Fiji's lower southern Lau islands?

3.3.2 Secondary research questions

- What are the unique requirements to achieve sustainable sea transport for the lower southern Lau islands? (e.g., trade imbalances, reliance on imports, quality of life measurements, etc.)
- What renewable energy technologies and shipping innovations are cost-competitive and offer reliable performance to meet the unique requirements of Fiji's domestic sea transport?
- How can a regional MFM framework be implemented to meet the needs of the communities and create local added value?

3.4 Hypotheses

Based on the theoretical framework and research questions, this thesis proposes four essential hypotheses:

a) The MFM model of domestic inter-island sea transport will benefit the local economies (i.e., create local added value) by maximizing the use of sustainable natural resources and domestic materials and energy, keeping financial resources within Fiji.

b) Implementation of the MFM model will require higher initial investment but prove economically viable and preferable over time.

c) To be successful, all key stakeholders will be required to take an active role in placing their priorities to the sustainability of domestic inter-island transport.

d) This model can be successfully replicated for Fiji's other domestic shipping routes as well as regional shipping within Oceania.

The main hypothesis (a) postulates that the MFM framework will provide four key benefits:

a) Reduce dependence on oil imports (and thus keep financial resources within Fiji);

b) Be sustainable in the sense that Fiji's government and the shipping operators will operate the shipping services at a profit rather than a loss;

c) Create local added value to the communities of the lower southern Lau islands by providing economic growth and green business opportunities; and

d) Minimize negative impact on the environment via reduced GHG emissions and ecologically sound shipping practices.

The proposed benefits listed above are depicted in Figure 3.2 below. As a resource-rich country, Fiji has the potentials necessary to support these hypotheses and the MFM model of sustainable inter-island sea transport for its domestic shipping sector. This thesis will analyze the data from the lower southern Lau route to test and either accept or reject the hypotheses, thus adding to the body of literature on sustainable sea transport in Oceania.

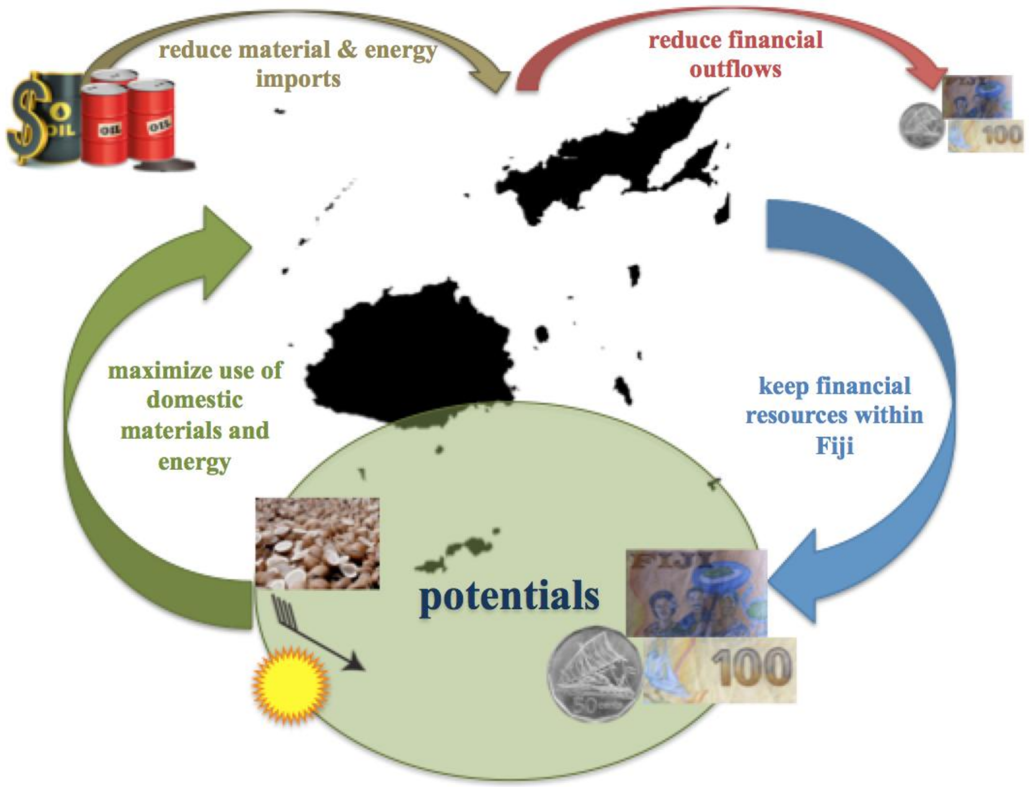

Figure 3.2: Proposed benefits of MFM model for sustainable sea transport (Source: Author's adaptation of MFM model as described in Heck, 2014, 27)

3.5 Research objectives

The research objectives are centered on the concept of regional MFM in application to answer the research question described above. The research objectives are:

a) Describe the unique requirements to support sustainable shipping practices among Fiji's lower southern Lau islands
b) Identify innovations in renewable energy technologies, hybrid power systems, and other sustainable shipping practices that are appropriate to the region
c) Compare the economic, environmental, and social factors of the various innovations identified in objective (b)
d) Introduce a feasible MFM model for sustainable shipping for the lower southern Lau islands and all of Fiji
e) Determine the effectiveness of minimizing the environmental impact and revitalizing the maritime transportation sector of the region using the innovations identified in objective (b), as applied to the model introduced in objective (d)
f) Evaluate the impact of this framework in relation to all concerned stakeholders

The research objectives listed above are the primary objectives identified to test the hypotheses and the MFM framework. Other less critical objectives exist and are discussed in further detail in Chapter 4.

3.6 Significance of this research

Sea transportation is the lifeline of Pacific island countries of Oceania, yet these countries remain at the periphery of the global economy. Often marginalized or neglected due to their small economies as compared with the major countries of the global shipping network, these countries have the potential to benefit tremendously from a sustainable and effective maritime transportation initiative. This research will examine one particular case to provide a regional MFM model of sustainable shipping that will contribute to the socio-economic development of the region. In today's interconnected world of instant communication and information exchange, sustainability should be at the forefront of any development goals; lessons learned from one scenario should be reviewed and tailored to improvements in others. An effective solution to provide sustainable shipping to the lower southern Lau islands should not be an isolated or forgotten effort.

The significance of this study is to provide practical solutions that can be realistically implemented for Fiji's domestic shipping. Thus, this research is not only an academic pursuit to identify and analyze the complexities of a socio-economic and related environmental problem, nor is it a simple understudy of previous research or findings. Indeed, this research is essentially an endeavor to improve the social, economic and cultural livelihoods of Lau islanders in an environmentally sustainable manner. Of course, it is worth reiterating that this thesis rests on the belief that no outside force can – nor should – induce development or change. No, the best solutions originate from within the community – in this case, the villagers and people on each of the five Lau islands in this study. Simply stated, this research is one outsiders understanding of a complex problem that can hopefully contribute to an effective and sustainable solution.

While the aim of this research is to analyze the theoretical aspects of one particular model of eco-efficiency, practical solutions may in fact be viable for Fiji and greater Oceania. Furthermore, the findings can be tailored to other regions of the world with similar characteristics, such as inter-island sea transport in the Caribbean Sea and Indian Ocean as well as coastal and river transport to equally remote, less-accessible communities in the developing world.

4 MFM methodology: Exploring the potentials

The case study of the lower southern Lau shipping route requires both primary and secondary data necessary for testing the hypotheses. The research design follows the MFM methodology,which can be considered a mixed-methods approach for two reasons. First, the MFM methodology contains two key components: the material flow analysis (MFA) and the material flow management implementation. Second, the research is mixed-methods for its material flow analysis (MFA), which contains both quantitative and qualitative data analysis. In general terms, the research will analyze the current situation, determine the potentials, and develop targets for implementation (Figure 4.1).

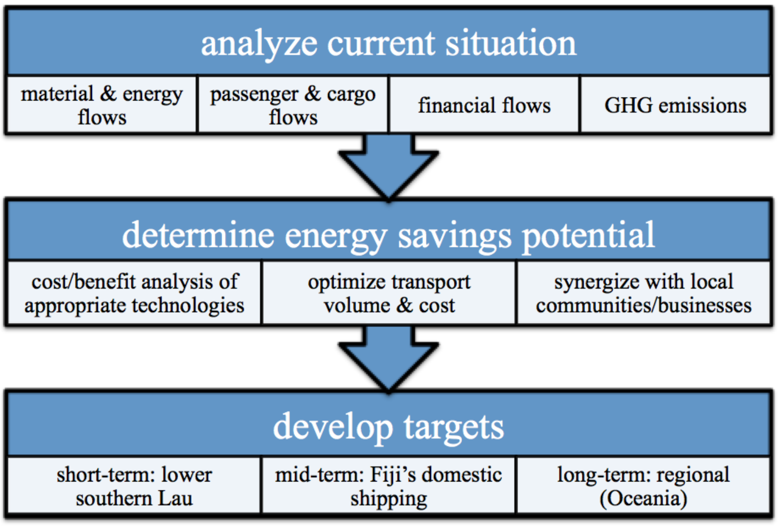

Figure 4.1: Overall methodology for sustainable sea transport in the lower southern Lau islands (Source: Author's creation)

The research process depicted in Figure 4.1is a condensed overview of the entire methodology of this thesis. This necessitates a more thorough description of this process. Therefore, to explain the methodology in detail, this chapter consists of the following sections: 4.1) aims of MFM methodology; 4.2) MFA: Mixed-methods data analysis; 4.3) MFM: Sustainable shipping solution; and 4.4) assumptions.

4.1 Aims of MFM methodology

The MFM methodology aims to thoroughly analyze a current business model, supply-chain, or other transfer of material and financial resources and develop a more energy/material efficient, environmentally sustainable, and economically viable alternative. Specifically, MFM has seven key aims that, when considered together, result in local or regional added value (Heck, 2014, 26):

a) Activate regional potential

b) Increase system efficiency

c) Decrease operating costs

d) Create stakeholder network

e) Create and maintain jobs

f) Support innovative small and medium enterprises (SMEs)

g) Create sustainable economy/society

Figure 4.2: Aims of MFM (Source: Author creation, adapted from Heck, 2014, 26)

The overall goal of MFM – regional or, in this case, *local* added value – is a combination of these seven factors (Figure 4.2). By identifying and activating the resource potential (e.g., solar irradiation, wind, copra, shipwright expertise, seafaring skills, etc.), engaging all key stakeholders, and meeting each one of the above aims as appropriate, sustainable shipping for the lower southern Lau islands can be viable.

This is achieved using the MFM methodology, which consists of the two essential components and their elements (adapted from Heck, 2014):

a) MFA
    i. Define system boundary
    ii. Quantitative data analysis
    iii. Qualitative data analysis
    iv. Key stakeholder assessment
b) MFM
    i. Brainstorm list of potentials
    ii. Rank and discuss all potentials with stakeholders
    iii. Formulate project list
    iv. Rank and discuss feasible projects with stakeholders
    v. Conduct economic feasibility study
    vi. Create MFM master plan

Both components and their elements areessential to the overall process. Together, the end result – MFM master plan – is a viable solution that provides the benefits of sustainable development and creates local or regional added value. Figure 4.3shows this methodological process.

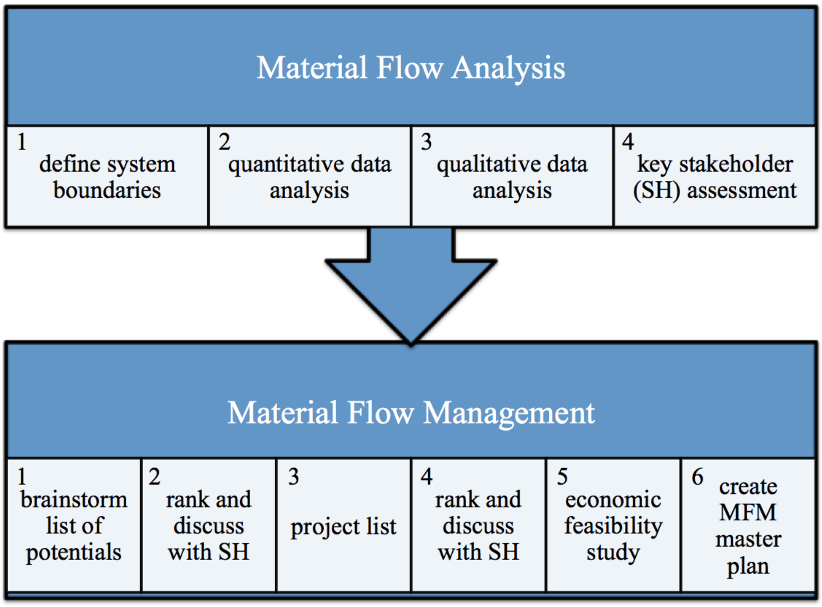

Figure 4.3: MFM methodology (Source: Author's creation, adapted from Heck, 2014)

4.2 MFA: Mixed-methods data analysis

The two primary methods of this research are a quantitative and a qualitative analysis of the route. The combination of quantitative measures and a qualitative case study of the route– a mixed-methods approach – provide the best results for the intended scope of research. This methodology applies directly to the route to the lower southern Lau islands, and subsequently, the results can extrapolated to sea transport within Fiji and the greater region. The MFA portion consists of two other important steps as well: defining the system boundary and a key stakeholder assessment. This section will describe each step of the MFA process in order as follows: 4.2.1) define system boundary; 4.2.2) quantitative analysis; 4.2.3) qualitative analysis; and 4.2.4) key stakeholder assessment.

4.2.1 Define system boundary

The first step in this process is defining the system boundary. This is crucial to limit the scope of the study to a clearly defined area. The system can be defined in various ways, such as geographical, administrative (i.e., political), economic, cultural, etc. (Heck, 2014, 47). Properly defining the system boundary is paramount to analyzing the data and interpreting the results. As discussed in Chapter 3, the underlying epistemology or theoretical basis of this research is the idea that everything is interconnected to everything else. Thus, defining a system boundary is a method necessary to test the hypothesis as a structured experiment. Of course, factors external to the system inevitably will interact and influence the variables and flows within the system in reality.

This thesis interchangeably uses the term *local* and *regional* in reference to the system limited to the lower southern Lau island route, unless otherwise specified. Also, in this regard and when explicitly stated, *local* MFM refers to the lower southern Lau island route and *regional* MFM include all other island routes within Fiji (i.e., national). On a larger scale and when explicitly stated, *regional*MFM indicates the region of either Melanesia or, more broadly yet, Oceania.

For this case, the system is defined as the capital Suva and the islands of the lower southern Lau group, namely Kabara, Flag, Ogea, Vatoa, and Ono-i-Lau. The system boundaries – geographical, cultural, administrative, and economic – are thus defined as the limits of these specific islands, also including the capital of Suva. Anything outside of the actual shipping route is considered external to the system.

4.2.2 Quantitative analysis

After the collection of both primary and secondary data, the quantitative analysis is the principle step needed to determine the current state of sea transport in the lower southern Lau islands. This is necessary to determine the requirements needed to develop sustainable alternatives to maritime transportation for this route, specifically in regards to alternative energy options and their economic viability.This quantitative analysis involves two major components:

a) Review of applicable sea transport data for Fiji's lower southern Lau islands. This includes, but is not limited to:
   i. Traffic volume – frequency, trip duration, route lengths, number of islands serviced, quantity of ships, etc.
   ii. Ship characteristics – displacement, age, engine type, operating speed, etc.
   iii. Cargo flows – total tonnage/passenger onload/offload at each stop, type of cargo, unit value of exports/imports, deadweight tonnage (DWT), etc.
   iv. Port constraints – port loading capacity, available time/equipment, etc.
b) Thorough assessment of environmental and social aspects. This includes, but is not limited to:
   i. Economic and social value of maritime trade to island communities
   ii. How island communities view and value their natural environment
   iii. Knowledge of seafaring and sustainable shipping practices
   iv. Impact of globalization and GHG emissions on social wellbeing

Conducting the quantitative data analysis on these topics listed above will provide comprehensive results to determine the most relevant findings in providing sustainable sea transport options for this route. The primary data for this case study was collected in March 2015 on site in Suva, Fiji and on the *MV Liahona* trip to the lower southern Lau islands. The actual data summary, details and analysis are provided in Chapter 5.

4.2.3 Qualitative analysis

The second part of this mixed-methods approach is a qualitative data analysis.This case study is a quasi-experimental design exploring the sea transport needs of the lower southern Lau islanders. This entailsthe collection ofprimary data by observing the lower southern Lau island route without any direct interference or actual test of variables on part of the researcher. This primary data collection was accomplished in March 2015. Secondary data was collected throughout 2015 and early 2016 to provide the most current information relevant to this study.

This mixed-methods process provides the necessary formula to integrate the data into an MFM framework for sustainable sea transport alternatives for the region. Additionally, this chosen methodology is most suitable for the theoretical basis of this study in consideration of the research objectives and associated limitations.

4.2.4 Key stakeholder assessment

The final part of the MFA is a key stakeholder assessment. First, all stakeholders and interested persons/organizations need to be identified. From this list, the relevance, influence, and engagement of each one is analyzed and ranked. The key stakeholders are those that are critical to the current sea transport route to the lower southern Lau as well as those that have the most influence and interest in creating a sustainable alternative.

4.3 MFM: Finding the best solution

After completion of MFA, the next step requiresdevelopment of sustainable alternatives and the best solutions for this particular case. This entails the MFM portion of the methodological process. Namely, it involves identifying the potentials (e.g., solar, wind, copra, shipwright knowledge, tourism, etc.) and, together with the key stakeholders, iteratively determining the most practical and achievable solution. The end result is the MFM master plan, a comprehensive business plan with detailed steps for financing, engaging stakeholders, and implementing the green business solution.

The focus of this research is the process itself as it relates to the chosen route; the MFA process comprises the most significant portion of the research. The MFM process, on the other hand, is presented here as the most-likely path rather than the determination of the most appropriate solution for this case. In other words, the iterative process of developing and selecting potentials, alternatives, and the best fit with key stakeholders is, in this case, conducted in a vacuum. The goal of this research is to explain the process and the most appropriate method for sustainable sea transport; it is not intended to provide an actual business plan (MFM master plan) developed jointly with the key stakeholders. However, for the sake of explaining the entire methodological process, each step must be included and assessed to complete the research. The following subsections will explain each iteration of the MFM process.

4.3.1 Brainstorm list of potentials

After through analysis of the information processed from the MFA, the first step of the MFM process is to brainstorm a list of potentials within the system that are potentially more sustainable than the status quo. Nothing should be disregarded in this step, as it is intended to provide a complete picture of all possible options – regardless of economic feasibility or other concerns. Examples related to this case can include the use of solar panels to reduce fuel consumption on the ship, processing copra and other organic material into useable marine biofuel, wind-assisted propulsion, and the use of skilled shipwrights to share their knowledge and construct vessels similar to the *Tai Kabara* (see Figure 2.6).

4.3.2 Rank and discuss all potentials with stakeholders

From the brainstorm list of all possible alternatives, the next step requires implementation of a measurable ranking system to evaluate each option. This ranking system should ideally be developed with input from the key stakeholders. If any key stakeholder is excluded at any stage of the MFM process, the likelihood of success will diminish; this is due to the fact that each key stakeholder has important influence in the final implementation of the MFM master plan. Once each option is weighed and ranked accordingly, the results should be distributed to all stakeholders for their awareness and to raise any issues early in the process.

4.3.3 Formulate project list

The top ranked items from the brainstorm list form the project list. Each of these top ranked items must be analyzed and scrutinized in more detail, providing a thorough understanding of the viability of each. This is a critical step in the iterative process and requires the most detailed and accurate comparison possible.

4.3.4 Rank and discuss feasible projects with stakeholders

Similar to the ranking of the options from the brainstorm list, a set of ranking criteria and weights determines the best options of all feasible projects. Likewise, stakeholder involvement in this step is crucial to the overall success of the final project.

4.3.5 Conduct economic feasibility study

The most highly ranked project as determined from the inclusion of all key stakeholders requires a complete economic feasibility study. This is a complex and thorough analysis of various scenarios that can affect the finances of the project. If the stakeholders agree – and if time permits – the top two or three ranked projects should be done in this manner to provide yet another more detailed comparison. This would add one additional iteration to the process, but it may be necessary if the projects are considered nearly equal in their viability.

4.3.6 Create MFM master plan

The final step of the MFM process is the creation of the MFM master plan. This is the final document that presents the entire plan of the project. It includes the projected timeline, budget, finances, procurement, logistics, and marketing, among others. When the MFM process is done in the methodological process described above with the inclusion of key stakeholders throughout, the final result is the best MFM master plan for the case.

4.4 Assumptions

In order for this thesis to properly test the hypotheses and follow the methodology as explained above, this thesis makes several prerequisite assumptions. First, the government observer data is assumed to be the most accurate. Further analysis reveals the unreliability and inconsistency of this assumption, however, it is the best data available for this research. Additionally, automatic diesel oil (ADO) – the fuel reportedly used aboard *MV Liahona* – is assumed to be equivalent in the pertinent ratings to marine diesel oil (MDO), or DMB. Finally, a key assumption is the total round-trip distance of the lower southern Lau route is 416 nautical miles, as opposed to 516 nautical miles. This is the most accurate estimate based on the actual chart data aboard *MV Liahona*, while the latter figure is consistently used in government documents. This 100 nautical mile difference can significantly alter the final numbers of analysis.

5 Findings: Navigating the way forward

In line with Fiji's Sustainable Energy For All (SE4All) report, one key objective of the transport sector is to "investigate the potential and cost-effectiveness of energy efficiency and renewable energy solutions for sea vessels" that will ultimately improve efficiency and reduce fuel consumption for Fiji's sea transport sector (Department of Energy, 2014, 4). Thus, the economic aspects of introducing these renewable energy systems in Fiji's sea transport must be analyzed sufficiently to determine profitability. Although the technology exists to drastically reduce GHG emissions from shipping, the most significant barriers for PICs are economic, especially those regarding policy and financing (Nuttall, 2014). This chapter provides the results of the data collection and field survey, and it is divided into three main parts: 5.1) current situation of domestic shipping; 5.2) lower southern Lau shipping route; and 5.3) MFM developments. These three sections analyze the current economic situation of the government subsidies to shipping franchises, the case study route of the lower southern Lau islands, and finally the possible economic benefits that renewable energy technologies can deliver.

5.1 Current situation of domestic shipping

Domestic shipping routes in Fiji are planned and coordinated by MoIT – specifically the Department of Transport Planning Unit (TPU). The vision of MoIT is "achieving higher economic growth and prosperity for Fiji through sustainable infrastructure", and the focus of TPU is to strengthen "the capability of Government to better co-ordinate transport planning and monitor policy and developments in the transport sector" (MWTPU, 2012, 12). As discussed here, domestic shipping is one such critical component to Fiji's economy, yet is economically challenged to develop in a sustainable and efficient manner. The remainder of this section provides the overall data and analysis of domestic shipping in Fiji, with particular emphasis on the uneconomical routes (as explained in section 5.1.1).

Despite the fact that domestic shipping is under purview of MoIT and the safety standards set by the Maritime Safety Authority of Fiji (MSAF), it is beset by myriad scheduling problems, inefficiencies, substandard performance, and unreliable service. One of the most significant ongoing complaints is the unchanging freight rate. The rates have not changed for over 20 years, leading shipping operators to impose “unreasonable and unjustifiable charges like handling charges, wharf charges, etc.” (Consumer Council of Fiji, 2012, 12).A story appearing in the Fiji Times in August 2015 after the commissioning of *MV Cagivou* for the GSS revealed other notable problems, including lack of adherence to schedules, unfair compensation, and poor management of the shipping operators (Wesley, 2015).[9] Lack of planning and preparation – not to mention proper maintenance and servicing – also leads to major setbacks for domestic shipping. In early 2014, the *MV Liahona* suffered a casualty to the main engine, requiring GSS to intervene and provide a replacement vessel during the several month long repair work (Loga, 2014). As recently as November 2015 a regular interisland servicing vessel sunk in Suva harbor (Narayan, 2015).

In sum, the current situation of domestic shipping in Fiji has ample space for improvement in reliability, safety, scheduling, and overall management. In this case, MFM can be considered a method not only for the sustainable development of domestic shipping, but also a means to ensure efficient and effective management of the overall service.

[9] The *MV Cagivou* costs FJD 5.7 million and brought the total number of GSS vessels to six. Prime Minister Bainimarama stressed the importance of this procurement: “This continuing upgrade of our ability to service the most isolated parts of Fiji is one of the most important things my Government has ever done. Because before we acquired these vessels, there hadn’t been a new ship on these routes for three decades” (Wesley, 2015).

5.1.1 Routes

Fiji's government classifies the shipping routes into two categories. The first is *economical routes* – those involving high capacity and volume of cargos and passengers; the second is *uneconomical routes* – those with less cargo and passengers (MWTPU, 2012b, 4). Although these categories have no specific delineation, the essential premise is that the uneconomical routes require subsidies in order to remain active (see section 5.1.2). Without these subsidies, there is a high probability that the shipping operators will cut their losses and stop operating these routes. As recognized in 2012, five economical and ten uneconomical routes operated in Fiji (see Table 5.1). In 2015, after implementation of thesuggestions from the franchise review (see Section 5.1.2), the ten uneconomical routes were consolidated and reduced to nine – combining the Northern Lau I & II into one, combining the Lomaiviti I & II into one, and adding a route to Cikobia (Nisha, 2016). The franchise operators, routes, and scheduling is thus subject to changes, again creating uncertainty in sea transport.

Table 5.1: Fiji's domestic shipping routes (Source: Author's edition, adapted from MWTPU, 2012)

No	Economical Routes	Vessel	No	Uneconomical Routes	Vessel
1	Levuka - Natovi - Nabouwalu	*Spirit of Harmony*	1	Northern Lau I	*
2	Suva - Levuka	*Sinu I Wasa*	2	Northern Lau II	*Lau Trader*
3	Suva - Koro - Savusavu - Taveuni	*Lomaiviti Princess I & II*	3	Upper Southern Lau	*Lady Sandy*
4	Natovi - Savusavu	*Westerland*	4	Lower Southern Lau	*Lau Trader*
5	Suva - Kadavu	*Sinu I Wasa&Lomaiviti Princess II*	5	Kadavu	*Uluinabukelevu*
-	-	-	6	Rotuma	*
-	-	-	7	YasawaMalolo	*YII*
-	-	-	8	Yasayasa	*Lady Sandy*
-	-	-	9	Lomaiviti I	*Lady Sandy*
-	-	-	10	Lomaiviti II	*

* No data available

5.1.2 Government shipping franchise scheme

In order to ensure accessibility for the remote populations on the outer islands, the Fiji government has to provide subsidies as an economic incentive to shipping operators. This not only ensures accessibility, but also provides the island residents with a more-or-less regular service that they can use to their advantage. Established in 1997, Fiji's Government Shipping Franchise Scheme (GSFS) aims to achieve the following objectives:

a) Introduce a shipping service to service uneconomical sea routes to maritime islands which would otherwise be un-serviced;
b) Promote private shipping operators and internal traders for movement of goods and cargoes;
c) Encourage the transportation of the maritime public between outer islands and major urban centers;
d) Incentivize transport operators through the support of a Government Subsidy to service uneconomical routes.

At the beginning of the GSFS in 1997, the operators received the subsidy on a monthly basis after the successful completion of their shipping route, calculated at a rate of 42% of monthly operating expenses. This rate was applied to eleven selected routes that had proven uneconomical to the shipping operators. Furthermore, the Fiji government has been the sole provider of the Northeast Vanua Levu route due to unavailability of vessels and inadequate incentive (and this will continue until the route achieves minimum commercial viability). More recently, however, the scheme changed, with the government contracting the shipping operators on an annual basis and receiving a subsidy at the rate of FJ$30 per nautical mile (MWTPU, 2014). In actual practice, the rate is set differently depending on the route in order to optimize the economic viability for both the shipping operators and government (see Appendix 1). Several factors contribute to the uneconomic aspects of Fiji's domestic shipping: including the low freight rates set by the government, which have not changed since 1993 (thus, the subsequent need of shipping operators to charge more than these official rates), the low demand and utilization of shipping services with respect to the high fuel and maintenance costs, and the relative remoteness and inaccessibility to any significant or profitable markets.

In 2014, the Fiji government conducted a thorough review of GSFS and proposed a new rate based on the following formula:

$$GSFS = 30\% - \left(\left(\frac{Sales - Costs}{Sales}\right) \times 100\right) \times Sales$$

Equation 1: FCC subsidy formula

By applying this to the actual performance of every uneconomical franchise route, the result would be a reduction in subsidy payments by 31%; however, this proposal does not recommend reducing the payments for the most uneconomical routes (MWTPU, 2014, 8). Furthermore, some recommendations were made to combine or change certain routes, although no alteration was recommended to the Lower Southern Lau route due to its current situation of being the least economically viable route. Table 5.2is an overview of this new proposal that took effect in April 2015, showing the current total of nine subsidized uneconomical routes. The data show that the recommendations for revising the subsidy scheme can benefit the government by lowering expenditures; however, in turn the shipping operators have voiced concerns that they will now have to absorb the price difference and incur an even lower profit margin.

Table 5.2: Uneconomical franchise routes and prices (Source: Author's edition, adapted from MWTPU, 2014)

No	Route	Subsidy (FJD/voyage)		Change (FJD/voyage)	New Franchised Rate (FJD/NM)	Frequency of visit	Subsidy (FJD/month)		Change (FJD/month)
		Current	Proposed				Current	Proposed	
1	Northern Lau (NLI & NLII)	$22,500	$18,000	-$4,500	$40.19	Fortnightly	$45,000	$36,000	-$9,000
2	Lomaiviti (LI & LII)	$15,500	$9,000	-$6,500	$45.00	Fortnightly	$31,000	$18,000	-$13,000
3	Upper Southern Lau (USL)	$14,000	$13,000	-$1,000	$31.20	Fortnightly	$28,000	$26,000	-$2,000
4	**Lower Southern Lau (LSL)**	**$18,000**	**$18,000**	**--**	**$34.90**	**Monthly**	**$18,000**	**$18,000**	--
5	Kadavu (K)	$10,000	$9,000	-$1,000	$47.80	Fortnightly	$20,000	$18,000	-$2,000
6	YasayasaMoala (YyM)	$12,000	$11,000	-$1,000	$39.10	Fortnightly	$24,000	$22,000	-$2,000
7	Yasawa (YM)	$8,000	$6,000	-$2,000	$36.10	Monthly	$8,000	$6,000	-$2,000
8	Cikobia (C)	$13,500	$13,500	--	$30.00	Monthly	$13,500	$13,500	--
9	Rotuma (R)	$25,000	$25,000	--	$30.40	Monthly	$25,000	$25,000	--
--	**TOTAL**	**$138,500**	**$122,500**	**-$16,000**	**--**	**--**	**$212,500**	**$182,500**	**-$30,000**

5.1.3 Cargo and passenger flows

Beginning in 2014, TPU required government observers to travel on all uneconomical routes to observe shipping operations and record data. This is a marked improvement in that the government now has the background data necessary for both quantitative and qualitative analyses of the shipping routes under the GSFS. However, this data is highly unreliable and inconsistent.

First, the method of quantifying the total cargo onloads and offloads is based solely on the government observer's rough estimate by visual observation. Specifically, during the field study the observer reported that each fully loaded boat that came alongside carried approximately four tons of cargo. Thus, based on the number of boats, one could ascertain the total cargo load; no accurate or reliable measure was utilized to record this data. Passenger transport is slightly more reliable, as the observer records the receipts and passenger log data provided by the shipping operator. However, during the field study there was a noticeable lack of proper accountability for embarking and disembarking passengers from each small boat that came alongside.Second, the recorded data is inconsistent between the government observer's estimates and that of the shipping operators. At the end of each voyage, the shipping operators provide their figures to the government observer. This includes cargo in and out, passengers in and out, and the total revenue from all four of those flows. The master spreadsheet reveals these abundant inconsistencies.

Despite these two concerns of unreliability and inconsistency, the data does provide a solid foundation in which to begin an analysis and make initial estimates. In an effort to remain consistent, and considering the handful of shipping operators and unknown accounting methods, the data shown in this thesis is that of the government observers.

Table 5.3: Aggregate cargo and passenger flows for uneconomical route, 2014 (Source: Author's edition, adapted from MoIT, 2015)

	Cargo flows (tons)		**Passenger flows (pax)**	
	In	**Out**	**In**	**Out**
January	265	234	740	573
February	155	196	356*	635
March	200	297	489	504
April	188	253	381	674
May	173	343	279	567
June	280	390	521	633
July	170*	202	392	307
August	319	226	871	665
September	302	441	313	945
October	230*	372	542	572*
November	164	285	565	794
December	206*	226*	957*	1000*
2014 total	**2,652**	**3,465**	**6,406**	**7,869**

* Data provided by MoIT 2014 Annual Report (2015); inconsistent with master spreadsheet (see Appendix 2)

The flows are divided into two groups: *inflows* and *outflows*. While no official source clarifies the actual meaning of these two, this thesis assumes that inflows are those goods and passengers coming into the port of Suva, and outflows are those going out to the remote islands. As such, the recorded data does not specify to the required detail of island and village level – only to the level of the route itself. This would be crucial data to determine which islands and villages utilize shipping services by volume and frequency. This point is a key recommendation for future studies, and will be mentioned in the conclusion.

5.1.4 Financial flows

Table 5.2 shows the subsidies that took effect in April 2015 for each uneconomical route, as well as the previous subsidy rate. A condensed version of the full financial flows for both cargo and passenger inflows and outflows is provided in Appendix 3 (adapted from the 2014 master spreadsheet provided by TPU). By analyzing this data and the information provided in Appendix 2, an effective comparison shows the average revenue for each route. The simple arithmetic calculation is presented in Table 5.4 for both cargo (Fiji dollars per ton per nautical mile) and passengers (Fiji dollars per passenger per nautical mile).

Table 5.4: Average revenue and subsidy prices for uneconomical routes, 2014

		Cargo revenue rate (FJD/t/nm)			**Pax revenue rate (FJD/p/nm)**			**GSFS (FJD/nm)**
	Route*	**In**	**Out**	**Average**	**In**	**Out**	**Average**	
1	USL	0.32	0.35	0.33	0.21	0.32	0.27	33.57
2	YyM	0.71	0.97	0.84	0.44	0.36	0.40	42.70
3	**LSL**	**0.39**	**0.59**	**0.49**	**0.46**	**0.32**	**0.44**	**43.27**
4	NLI	0.44	0.96	0.70	1.87	0.61	1.24	37.31
5	NLII	0.30	0.37	0.34	0.24	0.28	0.26	37.88
6	LI	1.22	1.39	1.31	0.45	0.49	0.47	57.14
7	LII	0.96	1.50	1.23	0.39	0.55	0.47	53.57
8	K	1.49	1.66	1.57	1.60	0.88	1.24	84.75
9	R	0.31	0.31	0.31	0.19	0.23	0.21	30.41
10	YM	0.32	0.49	0.41	0.21	0.19	0.20	43.72
		Average cargo		0.75	Average pax		0.52	

* See Table 5.2 for the shipping route codes (e.g., LSL = Lower Southern Lau, etc.)

Based on these financial flows from 2014, the average rate of cargo revenue is 0.75 FJD/t/nm and the average rate of passenger revenue is 0.52 FJD/t/nm. The Rotuma route has the lowest rate of cargo revenue (0.31 FJD/t/nm) and the YasawaMalolo route has the lowest rate of passenger revenue (0.20 FJD/p/nm). The lower southern Lau route actually ranks on neither extremity of the revenue or subsidy amount. However, its cargo revenue is 35.08% lower than the average, and itspassenger revenue is 24.40% lower than the average.

Furthermore, considering the total population served (see Appendix 1) and the fact that it is divided between five distinct islands, the argument can be made that it is still least economical in terms of voyage duration, operational requirements, and logistical effort involved. The only route with a significantly greater voyage distant than the lower southern Lau is to Rotuma. However, key differences include the fact that Rotuma has port infrastructure (an actual wharf/jetty), alternate accessibility (regular air service), and is a single island voyage.

5.2 Field study: *MV Liahona* and the lower southern Lau shipping route

The field study took place in March 2015. The purpose was to record a sample set of data from the lower southern Lau shipping route. This is a monthly domestic shipping route that services five small islands of Fiji’s eastern Lau island group – specifically, Kabara, Fulaga, Ogea, Vatoa, and Ono-i-Lau. The servicing vessel for this franchised route is *MV Liahona*, operated by South Island Shipping Services (Figure 5.1). The study consisted of first hand observation of the route, primary data collection, an interview with the owner of the shipping company, and a qualitative sample of passengers during the voyage.This provides the baseline scenario upon which sustainable shipping alternatives can be more effectively considered and substantiated as viable solutions.

Figure 5.1: ***MV Liahona*** **cargo onload, Suva** (Source: Author's own photo, March 2015)

The vessel that services this route – *MV Liahona* – has operated both this route and the northern Lau II route since October 2013 (see Table 5.5 for ship data). Its prior owner used it as a fishing vessel with its homeport on the island of Kadavu. It is a typical vessel that services Fiji's outer islands: over 25 years old running on outdated propulsion and auxiliary systems. As mentioned in section 5.1, *MV Liahona* had an engine casualty that rendered it unable to operate as scheduled in early 2014 – only months after it began operating as a franchise vessel. This is not an uncommon problem among shipping operators, and it only adds to the unreliable domestic sea transport service in Fiji.

Table 5.5: ***MV Liahona*** **data** (South Island Shipping Services, 2015)

Year built:	May 1981	Cruising speed:	8 knots
Call sign:	3DUM	Maximum speed:	10 knots
Length:	27 meters	Fuel consumption:	-
Width:	5.8 meters	- At sea:	100 l/hr
Draft:	2.6 meters	- In port:	30 l/hr
Passenger capacity:	150 pax& crew	Main propulsion engine:	Cummins KT19, 450kw
Cargo capacity:	150 tons	Generators:	2x Yanmar 240 KVA
Current operation:	Since October 2013		1x Cummins 6BT 65 KVA

NOTE: All information reported from South Island Shipping Services and approved by Government Tender Board, 18 February 2015; not all information corresponds to other sources (e.g., cargo capacity as recorded by MWTPU in Appendix 1)

The eleven members of the *MV Liahona* crew consist of three engineers (including the chief engineer) and eight deck personnel (including the captain). According to the chief engineer, *MV Liahona* has the following tanks of note:

- 1x fuel bunker tank (12,000 liters)
- 1x fuel service tank (2,000 liters)
- 2x potable water tanks (10,000 liters each)

The typical generator configuration is to operate the Cummins 6BT underway and to operate one Yanmar KT19 while in port or anchored near an island. The last recorded entry in the engineering log (January 2015) noted the following:

- Main engine run time: 56 hours
- Generator run time:
  - Nr 1 (Cummins): 61 hours
  - Nr 2 (Yanmar): 1 hour
  - Nr 3 (Yanmar): 78 hours
- Total fuel consumption:
  - Tank filled to: 6000 liters
  - Consumed: 5600 liters
  - Remain: 400 liters

Furthermore, the chief engineer noted that the fuel price (automatic diesel oil) in March 2015 was 2.20 FJD/liter. As a vessel operating under the GSFS, they pay the government concession rate of 1.72 FJD/liter. This data provides a reference point to compare and develop alternative options that are explored in section 5.3.

5.2.1 Islands serviced

The five islands of the lower southern Lau route are remote, pristine, and breathtakingly beautiful. They are far removed from the modern amenities and conveniences; the only means of accessing the main island of VitiLevu is via this sea transport route. No direct link exists between each island itself and Suva. As such, if a villager from Kabara has to go to Suva for medical attention or schooling, he or she must spend several days on the voyage to the more remote islands before reaching Suva. Likewise, if a villager must return home to Ono-i-Lau from Suva, he or she inevitablymust spend several days on the voyage to the other four islands serviced before reaching home. Additionally, no known regular transport exists between each of these islands, however small boat travel between islands such as Fulaga and Ogea are likely. During the field study, a rarely sighteddugout canoe known as a *takia*was witnessed in Fulaga, with the elderly fisherwoman bringing in her fresh catch for the evening (Figure 5.2).

Figure 5.2: Woman steering *takia*, Fulaga (with *MV Liahona* in background) (Source: Author's own photo, March 2015)

The one exception to this transport scheme is for Ono-i-Lau: this extremely remote island cluster has an airstrip, and a domestic airline services the island biweekly. The reported airfare is 432 FJD one way, making it prohibitively expensive for the average islander.

Depending on your mindset, life on these remote islands may be considered slow-paced, serene and tranquil on the one extreme, or challenging, arduous and tedious on the other. All of the communities observed during this field study rely on rainwater for drinking, diesel fuel imports for running the boat engines and generators, and seafood/handicraft exports as a source of income. Some villages have small photovoltaic cells for individual lights or other low-power use. Additionally, each island has a small primary school and eithera medical clinic or nurse’s station. In sum, sea transportation is vital for the essential services and economic livelihoods of the villagers, as it is the only means linking the outer islands with the resources of the capital.

Table 5.6: Lower southern Lau islands (Author, March 2015)

Island name	Population**	Area (km^2)	Distance from prior port (nm)	Arrival time/date	Departure time/date	Duration of stop (h:m)
Suva*	*	*	*	*	1220, 23 March	*
Kabara	432	31	160	0742, 24 March	1102, 24 March	3:20
Fulaga	292	18.5	28	1443, 24 March	1805, 24 March	3:22
Ogea	94	13.3	6	1926, 24 March	~0100, 25 March	5:34
Vatoa	249	4.45	42	0727, 25 March	2145, 25 March	14:18
Ono-i-Lau	470	7.9	56	0559, 26 March	1812, 26 March	12:13
Suva*	*	*	224	~1900, 27 March	*	*
Total	**1537**	**75.15**	**416**			

* Suva is port of origin; thus, data not applicable for purposes of this research
** Based on Fiji’s 2007 census data

From the field survey, Kabara, Fulaga, and Ogea primarily export traditional wood handicrafts, copra dominates the local economy of Vatoa, and seafood is the main commodity of Ono-i-Lau. Table 5.6 summarized the key data for each of the five islands. Operations in Ogea were the most difficult due to complete darkness and low tide, thus it required a far away anchorage and more dangerous small boat operations. The stop in Vatoa was the longest duration for two reasons: the antiquated lighthouse required a government survey and *MV Liahona* should weigh anchor at night to ensure an early morning arrival in Ono-i-Lau.

5.2.2 Field survey route results

Specific to the purposes of this case analysis, the servicing vessel *MV Liahona* used 5600 liters of marine diesel oil (MDO) on the March 2015 voyage.[10] The MDO consumerswere primarily its single Cummins KTA19-M3-600 marine engine for main propulsion as well as three diesel generators: one Cummins 6BT 5.9-GM83 (65kVA) and two Yanmar 6NY16L-HW (240kVA). According to the Chief Engineer of *MV Liahona*, the price of fuel in March 2015 was 2.20 FJD/l; however, the government provides a fuel concession for domestic shipping services at the price of 1.72 FJD/l. Thus, the 5,600 liters of fuel multiplied by the government discount rate of 1.72 FJD/l results in 9,630 FJD in fuel cost for the round trip voyage. This equates to 115,560 FJD per annum.

Next for the March 2015 field survey, Table 5.7 shows the official government estimate of cargo and passenger flows. The loading operations were time consuming and required both manpower and mechanical assistance. *MV Liahona* has a bow crane that was necessary for all of the heavy cargo, such as the vessels own motorboat, numerous oil drums, livestock, and other large, bulky items. At one point the cable of the crane snapped, but with makeshift rigging from the inventive crew, the crane was restored to a semi-operational capability. The reel could no longer extend or retract the cabling, but the crane arm itself was able to compensate for lifting and lateral movement.

Table 5.7: Cargo and passenger flows, March 2015 (Author, March 2015)

Segment	Cargo (tons)	Passengers
Suva – Lau islands (outflows)	50	34
Outer islands – Suva (inflows)	80	83
- Kabara – Suva	10	2
- Fulaga – Suva	10	5
- Ogea – Suva	20	5
- Vatoa – Suva	20	17
- Ono-i-Lau – Suva	20	54

[10] According to the Chief Engineer of *MV Liahona*, the fuel used on board is automatic diesel oil (ADO). Thus, the likeliest comparison is marine diesel oil vice heavy fuel oil (HFO).

MV Liahona itself had one small boat to transfer cargo and passengers at each island, but each of the villages on the islands had one or several motorboats as well. Figures 5.3 to 5.5 below show the method of operations. Significantly, no port infrastructure exists in any of the five islands, and the entire procedure requires a combined effort of every fit person.

Figure 5.3: Load operations I (Fulaga) (Source: Author's own photo, March 2015)

Figure 5.4: Load operations II (Ono-i-Lau) (Source: Author's own photo, March 2015)

Figure 5.5: Load operations III (Fulaga) (Source: Author's own photo, March 2015)

5.2.3 GHG emissions

In accordance with the bottom-up emissions methodology from the Third IMO GHG Study (IMO, 2014, 123), the most appropriate way to estimate GHG emissions is as follows:

1. Identify baseline emissions factors following the recommended hierarchy;
2. Covert energy-based baseline emission factors (g pollutant/kWh) to fuel-based emission factors (g pollutant/g fuel consumed);
3. Adjust emission factors for specific fuel consumed by engine;
4. Adjust actual emissions factor based on variable engine loads.

For the small scale of this research, however, these four steps are not entirely necessary. The Third IMO GHG Study (IMO, 2014) has determined most of the guidelines and data for the purpose here. Also of note, "the carbon content of each fuel type is constant and is not affected by engine type, duty cycle or other parameters when looking on a kg CO_2 per tonne fuel basis" (IMO, 2014, 124). The baseline CO_2emission factor for MDO is 3,206 kg CO_2/tonne fuel (IMO, 2014, 124). Since the specific fuel used is unknown, a key assumption stated earlier is that the fuel is MDO, also known as DMB. Accordingly, the density for DMB at 15°C is 900 kg/m^3. This is necessary to calculate the total CO_2 emissions.

Thus, *MV Liahona* used 5,600 liters of MDO, equivalent to 5.04 metric tons of fuel. Using the baseline CO_2 emission factor for MDO, *MV Liahona* produced a resultant 16,158.24 kg CO_2 for the March 2015 lower southern Lau voyage. At this level – and considering the fuel is MDO – all other GHG emissions are statistically insignificant. Table 5.8 summarizes this data below. Assuming this value is the typical monthly CO_2 emission level, *MV Liahona* emits 193,898.88 kg CO_2 annually – or roughly 194 metric tons per year.

Table 5.8: CO_2 emissions from field study (Author, March 2015)

Measure	Units	Value
fuel consumption	liters	5,600
density (15°C)	kg/m^3	900
baseline CO_2 emission factor	kg CO_2/ton fuel	3,206
total CO_2 emissions	$kgCO_2$	16,158.24

5.2.4 Interview and questionnaire

The field study included one interview with the owner of South Sea Shipping Services and a short questionnaire for a sample of passengers on the voyage. Due to limiting factors such as time constraints and insufficient network development, other shipping operators and key stakeholders in the domestic sea transport industry were not included in the interview section. Also, the questionnaire only applied to a fraction of the total passengers, mainly due to the language barrier. However, both the interview and questionnaire provide a basic understanding of the current situation of domestic shipping within Fiji.

The interview occurred on March 19, 2015 in the office of Mr. UlaiasiBaivatu, the owner of South Island Shipping Services. He is an architect by profession, but this shipping company is a side business of his. The ten questions asked during the interview are provided in Annex 5. The following two paragraphs are a condensed summary of the Mr. Baivatu's responses.

As a businessman from Kadavu, Mr. Baivatu had the opportunity to purchase an old fishing vessel and invest in shipping services to Kadavu. Per government request, he sent *MV Liahona* to service the Lau islands. At first, there were many problems; a significant engine problem required him to purchase a new engine and diesel generator from China in 2014. As of March 2015, around 25 employees worked for South Island Shipping Services; additionally, Mr. Baivatu has a small wholesale shop in Samabula to sell the goods and fish imported from the outer islands.

The most significant barrier to his operations is fuel cost; as such, his idea is to invest in inverters for underway steaming without using the generators. Furthermore, his operations realize a profit during peak season (December and January) or if the voyage has over 50% passenger capacity (equivalent to approximately 75 passengers). Otherwise, the GSFS is necessary to continue the shipping operations. *MV Liahona* also services the Northern Lau islands once every month; the turnaround time must be around four to five days between operations. Anything beyond eight days results in a net loss. The biggest problem now is that the freight cost set by the Fiji Commerce Commission has not been updated since 1992; this forces shipping companies to charge more than the official rate just to ensure they can cover the cost of operations. Mr. Baivatu has not thought about retrofitting sails, adding solar panels, or any other type of renewable energy mix, and he believes the initial cost and required installation time offset any possible gains. In sum, the interview highlighted the fluctuating nature of Fiji's domestic shipping operators and the external variables that affect these vulnerable sea routes.

On the voyage itself, sixteen of the 107 total passengers responded to the questionnaire. This survey provides a representative sampling of demographic and travel-related data of the passengers, shown in Table 5.9 below. Notably, most passengers travel for medical, education, or family purposes, and the few passengers who travel regularly are primarily village representatives, government employees, or religious leaders. This reflects the fact that most villagers have no need to leave their islands other than for medical care or for their children's higher education.

Table 5.9: Passenger survey results, March 2015 (Author, March 2015)

	Sex	Travelling w/children	Age	Occupation	Residence	Final destination	Purpose of travel	Frequency of travel
1	F	-	35	Mother	Fulaga	Fulaga	Medical visit, Suva	Infrequent
2	F	-	38	Mother	Fulaga	Fulaga	Funeral, Suva	Infrequent
3	F	1 yr. old daughter	32	Mother/artisan	Suva	Ogea	Family visit	First time after 8 years
4	M	-	60	Village representative in provincial council	Vatoa	Vatoa	Taking family to Suva for children's education	3-4 trips/year
5	M	-	31	Taro farmer	Kabara	Kabara	Family visit	5 trips/year
6	F	-	38	Mother	Vatoa	Vatoa	Taking daughter to Suva for education	First time
7	F	2 children	52	Mother	Ono-i-Lau	Ono-i-Lau	Medical visit, Suva	Infrequent
8	F	-	45	Mother	Vatoa	Vatoa	Taking son to Suva for education	1 trip/year
9	F	2 children (1 newborn)	27	Mother	Fulaga (originally Kabara)	Fulaga	Medical visit, Suva (deliver baby)	Frequent
10	F	2 children (1 newborn)	32	Mother	Fulaga	Fulaga	Medical visit, Suva (deliver baby)	1 trip/year
11	M	-	50	Farmer/wood carver	Fulaga	Fulaga	Jehovah's Witness Church conference, Suva	1 trip/year
12	M	-	54	Gov't employee (electrician)	Suva	Suva	Vatoa lighthouse survey	Frequent
13	M	-	34	Gov't employee (construction)	Suva (originally Kadavu)	Suva	Vatoa lighthouse survey	Frequent
14	M	-	44	Methodist minister	Vanua Levu	Koro	Annual Methodist ministry meeting in Koro (currently completed first of two year assignment in Ono-i-Lau)	4-5 trips/year
15	M	-	24	Farmer	Suva	Suva	Cricket tournament, Suva (1 month)	1 trip/year
16	M	-	23	Teacher	VitiLevu	Totoaya	Duty assignment transfer after initial 2 month assignment in Vatoa	First time

A basic survey regarding the sea transport and voyage consisted of four basic categories: cost, comfort, duration, and frequency of trips. The respondents had the following options for each category: (1) very unsatisfied; (2) unsatisfied; (3) average; (4) satisfied; (5) very satisfied; and not applicable. The response rate was 100%, and Table 5.10 shows the response data. The average responses show that passengers are most unsatisfied with the high cost of the journey (average score 1.5) and have a below average satisfaction level with the comfort level (average score 2.625). Both duration and frequency of the voyage are average – neither satisfied nor unsatisfied.

Table 5.10: Passenger questionnaire response data, March 2015 (Author, March 2015)

Respondent	Cost	Comfort	Duration	Frequency (Scheduling)
1	1	3	2	3
2	1	3	2	3
3	1	2	4	3
4	2	2	5	5
5	1	3	2	2
6	1	4	5	5
7	1	3	3	3
8	1	2	3	3
9	1	3	2	3
10	1	2	3	3
11	3	3	3	5
12	2	2	3	2
13	3	3	4	2
14	1	2	2	2
15	2	2	3	2
16	2	3	2	2
Average	**1.5**	**2.625**	**3**	**3**

This sampling of data provides valuable information regarding domestic sea transport to the lower southern Lau islands. The dissatisfaction from the high cost of the journey reflects the relatively low disposable income of villagers on these islands. Related to the cost, passengers expect greater comfort on the trip. This reflects the poor accommodation offered: no seats are available, deck space is secured only on a first-come, first-serve basis, and extra expenses are required if one opts for meals. On the final leg from Ono-i-Lau to

Suva, many passengers were sitting and sleeping on the weather decks and passageways, as all deck space in the passenger holds was occupied.

5.2.5 Key stakeholder involvement

While many individuals and organizations are interested in sea transport to the lower southern Lau islands, they can be categorized into key stakeholders, stakeholders (general), and interested parties. Only the key stakeholders are crucial to promoting the sustainable sea transport future. In this case, there are really only three key stakeholders, defined in these broad groups:

- Private shipping operator
- Village chiefs
- Government

Specifically, these are, respectively, Mr. Baivatu of South Island Shipping Services; the chiefs from the islands of Kabara, Fulaga, Ogea, Vatoa, and Ono-i-Lau; and the Ministry of Infrastructure and Transport. These key stakeholders and their interest and motivation are shown in Table 5.11. A crucial aspect of MFM for a sustainable sea transport route is properly incentivizing and promoting the interests of these parties. Their full-fledged support is essential to ensure success. Other stakeholders – such as MSAF, Fiji Commerce Commission, and research agencies – are relevant, but their committed involvement is not as crucial.

Table 5.11: Key stakeholder involvement (Author, 2016)

Key Stakeholder	Interest/motivation
South Island Shipping Services	Maximize profit
Ministry of Infrastructure and Transport	Ensure reliable outer-island connectivity
Village chiefs from each island (Kabara, Fulaga, Ogea, Vatoa, Ono-i-Lau)	Guarantee villagers have adequate access to goods and services in Suva

5.3 MFM developments

After reviewing the current situation and findings from the field study, this research now explores four alternative scenarios to the current model, namely: 1) wind, 2) solar, 3) biofuels, and 4) a combination of renewables. Each of these systems has advantages and disadvantages, and weights corresponding to the needs of the case study will help develop a list of ranking and priority. This section first explores the four main potentials, ranks them according to route suitability, and then develops a project list to explore their feasibility.

5.3.1 Potentials

In 2015, International Renewable Energy Agency (IRENA) published a study entitled *Renewable energy options for shipping* (Mofor, Nuttall& Newell, 2015). This guide compared several variants of wind, solar, biofuels, and wave power systems; the applicable systems for the lower southern Lau route are summarized in Table 5.12 below:

Table 5.12: IRENA's summary of renewable energy technology applications (vessels <400 metric tons) (Adapted from Mofor, Nuttall, & Newell, 2015, 10-11)

		Retrofit application		New build application	
		Current	**Potential**	**Current**	**Potential**
Wind	Soft sails	In commercial use	High	In commercial use	High
	Fixed wings	Concept	Medium	In commercial use	Medium
	Rotors	Proof-of-concept	Medium	Proof-of-concept	High
	Kites	Design	Medium	Design	Medium
	Turbines	Concept	Low	Concept	Low
Solar PV	Main propulsion	Design	N/A	In commercial use	Low
	Auxiliary propulsion	Proven	Medium	In commercial use	Medium
	Ancillary power	Design	Medium	Design	Medium
Biofuels	1st generation*	Proof-of-concept	Medium	Proof-of-concept	Medium
	2nd generation*	N/A	N/A	Concept	High
	3rd generation*	N/A	N/A	Concept	High
Wave	Main propulsion	N/A	N/A	Proven	Low
	Auxiliary propulsion	N/A	N/A	Concept	Low

■ High ■ Medium ■ Low ■ N/A

* 1st generation refers to conventional biofuel carbon derived from sugar, lipid, or starch directly extracted from plant; 2nd generation refers to advanced biofuel carbon derived from cellulose, hemicellulose, lignin or pectin; 3rd generation refers to advanced biofuel carbon derived from aquatic autotrophic organisms such as algae (for more information see European Biofuels Technology Platform http://www.biofuelstp.eu/advancedbiofuels.htm)

Based on the data in Table 5.12, the most realistic options for both retrofit and new build applications that can benefit this route meet both of the following two criteria:

a) Currently in the commercial use, proven, or proof-of-concept stage; and

b) High or medium potential use.

These selection criteria eliminate all options with low potential or in the design, concept, or not applicable stages of current application. Thus, the technologies that meet the criteria above are the following:

a) For retrofit applications:

   i. Wind: soft sails and rotors

   ii. Solar PV: auxiliary propulsion

   iii. Biofuels: 1^{st} generation

b) For new build applications:

   i. Wind: soft sails, fixed wings, and rotors

   ii. Solar PV: auxiliary propulsion

   iii. Biofuels: 1^{st} generation

Based on this information, retrofit and new build applications have, respectively, four and five technology options in total. To reiterate the purpose of selecting one or more of these technologies, the goal is to ensure a more sustainable sea transport system for the lower southern Lau islands. This entails meeting the three critical aspects of sustainable development: economical feasibility, environmentally beneficial, and socially acceptable.Figure 5.6depicts these technological options under the umbrella of sustainable development.

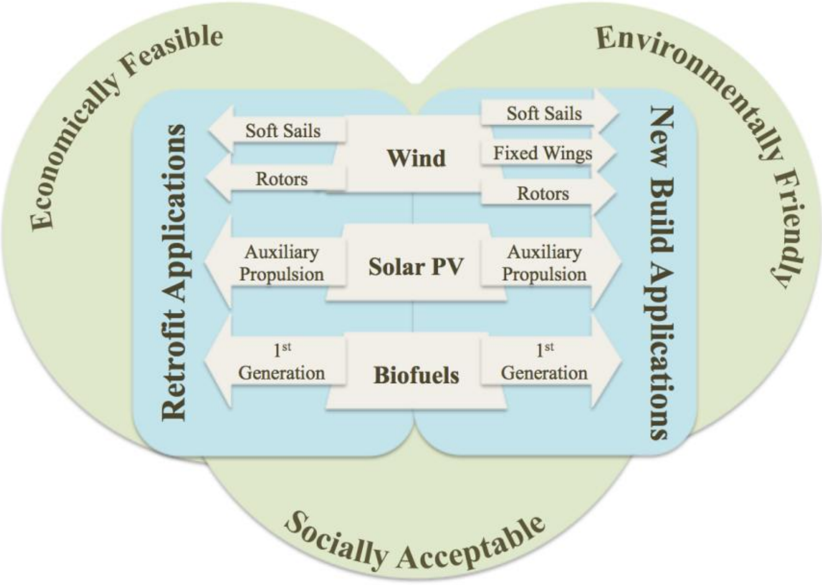

Figure 5.6: Renewable energy technology options for lower southern Lau route (Source: Author, 2016)

5.3.2 Ranking, project list, and feasibility

The next logical step in the process of technology selection is to properly rank the above options in terms of their economic, environmental, and social costs and benefits.Several methods exist to systematically evaluate these options to determine all possible outcomes and scenarios. However, due to the limited scope of this thesis, only a scorecard template provides a valid example to build upon for future studies (see Table 5.13). This basic design provides ten factors for comparison of each potential application with a standardized scoring system (1 to 10) and weight for each factor (1 to 5). In this case, annual costs are more likely of greater importance to the owner/operator than total lifetime cost, so operational lifetime is relevant as a separate means of comparison only. Obviously, a more robust scorecard can provide greater refinement in the evaluation, but for this template meets the scope of this small-scale shipping route.

Table 5.13: Balanced scorecard for renewable energy application in sustainable sea transport (Author, 2016)

Sustainable sea transport factors*			Weight**	Retrofit Applications: Wind – Soft sail	Retrofit Applications: Wind – Rotors	Retrofit Applications: Solar PV – Auxiliary Propulsion	Retrofit Applications: Biofuels – 1st Gen.	New Build Application: Wind – Soft sail	New Build Application: Wind – Fixed Wings	New Build Application: Wind – Rotors	New Build Application: Solar PV – Auxiliary Propulsion	New Build Application: Biofuels – 1st Gen.
Economic	1	Investment costs	4									
	2	Annual O&M costs	4									
	3	Estimated annual savings (e.g., from lower fuel costs, etc.)	3									
		Economic Factor Subtotal										
Environmental	4	Annual GHG abatement	5									
	5	Potential oil spill prevention	2									
	6	Other environmental benefits	2									
		Environment Factor Subtotal										
Social	7	Acceptance by chief	5									
	8	Passenger approval (e.g., potential for reduced fare, etc.)	4									
	9	Employment opportunities	3									
	10	Renewed interest in seafaring heritage	2									
		Social Factor Subtotal										
		Operational lifetime (years)										
		Total										

* all factors valued on a scale of 1 to 10 based on the following table:

		value	1	2	3	4	5	6	7	8	9	10
1	Investment costs	1000' FJD	>1,000	900 - 1,000	800 - 900	700 - 800	600 – 700	500 – 600	400 – 500	300 – 400	200 – 300	<200
2	Annual O&M costs	1000' FJD	>20	18 – 20	16 – 18	14 – 16	12 – 14	10 – 12	8 – 10	6 – 8	4 – 6	<4
3	Estimated annual savings (e.g., from lower fuel costs, etc.)	1000' FJD	<20	20 – 30	30 – 40	40 – 50	50 – 60	60 – 70	70 – 80	80 – 90	90 – 100	>100
4	Annual GHG abatement	tons CO2	0 - 20	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 180	180 - 200	>200
5	Potential oil spill prevention	%	<10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
6	Other environmental benefits	1 to 10	1	2	3	4	5	6	7	8	9	10
7	Acceptance by chief	1 to 10	1	2	3	4	5	6	7	8	9	10
8	Passenger approval (e.g., potential for reduced fare, etc.)	1 to 10	1	2	3	4	5	6	7	8	9	10
9	Employment opportunities	1 to 10	1	2	3	4	5	6	7	8	9	10
10	Renewed interest in seafaring heritage	1 to 10	1	2	3	4	5	6	7	8	9	10

** weight valued on a scale of 1 to 5 as follows: 1 – least important; 2 – slightly important; 3 – important; 4 – very important; 5 – extremely important

Furthermore, the complexity of evaluating different technologies in their entirety must be set aside in this thesis for the following reasons expounded by the IRENA study: 1) varying stages of design and development; 2) insufficient data on final costs and benefits; and 3) insufficient comparative data on externalities (Mofor, Nuttall, & Newell, 2015, 34).

An example of installing a solar photovoltaic system illustrates the uncertainty and insufficient data to evaluate these technologies. First, the total cost of a solar investment is determined by the cost of solar panels and inverters – assuming installation costs are included (Glykas, Papaioannou, &Perissakis,2010). This is shown in Equation 2 below:

$$C_{investment} = C_{solar\_panels} + C_{inverters}$$

Equation 2: Total cost of solar investment

Next, the net present value (NPV) can be factored in to provide an additional measure of economic viability. Equation 3 shows the NPV in the year k, for surface S and with solar radiation density π as follows:

$$NPV(\mathrm{k}, \mathrm{S}, \pi) = -C_{investment} + \sum_{k=1}^{k} \frac{Profit(k, S, \pi)}{(1+r)^k}$$

Equation 3: Net Present Value of solar option

Furthermore, the cost-benefit analysis of installed photovoltaic systems on merchant marine vessels significantly depends upon the annual average increase of the fuel oil, the area of operation (sunlight concerns) and costs of implementation (Glykas, Papaioannou, &Perissakis,2010). These are but a few of the variables necessary to sufficiently fill out the scorecard and ultimately rank the different technological applications. Additional challenges arise when, for example, one must rank the social aspects or other, smaller environmental benefits. Hence this thesis does not delve into actual evaluation of the various renewable energy technologies.

In closing this chapter, the findings of the study lay the groundwork for determining the sustainable alternatives to the current lower southern Lau island route. The following chapter discusses the results and their implications for sustainable sea transport in Fiji.

6 Discussion: Riding the tide of sustainability

As the tide of sustainability is on the rise, decision-makers would be prudent to explore and promote appropriate sea transport systems. This tide will reach every aspect of the economy and society, and this thesis contributes to one very small yet exemplary sea transport route of the lower southern Lau islands. The discussion herein assesses the findings of chapter 5 in terms of the seven key aims of MFM (see section 4.1 and Figure 4.2) that, in sum, create local (regional) added value. This chapter approaches each of the seven key aims of MFM in an effort to determine the benefits and drawbacks of this approach for a sustainable sea transport model.

6.1 Activating local potentials

The first key aim of MFM is to activate local potentials. This entails both natural potentials of the local Lau environment as well as the knowledge, skills, and culture of the communities. In this case, the local potentials available are:

a) Natural potentials
   i. Wind
   ii. Solar irradiance
   iii. Copra
b) Community potentials
   i. Lau seafaring heritage
   ii. Kabara shipwright expertise
   iii. Vatoa copra production

This list indicates the local potentials available for activation with the introduction of relevant renewable energy technologies. It does not indicate all potentials – such as the limited copra production on other islands or the traditional *vesi* supplied from Kabara – for these are extraneous to the application of the possible technologies.Table 6.1 links the technologies with relevant local potentials, thus illustrating the theoretical usefulness of developing a locally relevant sustainable sea transport scheme.

Table 6.1: Local potentials available for relevant renewable technology applications (Author, 2016)

Technology	Application	Natural Potential	Description	Community Potential	Description
Soft sails	Retrofit / New Build	Wind	Average annual wind speed = 6-8 mph, steady (SE trade winds)*	Lau seafaring heritage/Kabara shipwright expertise	Local experience with both sailing and ship construction; waning knowledge
Fixed wings	New Build	Wind	Average annual wind speed = 6-8 mph, steady (SE trade winds)*	Lau seafaring heritage	Local experience with sailing; waning knowledge
Rotors	Retrofit / New Build	Wind	Average annual wind speed = 6-8 mph, steady (SE trade winds)*	Lau seafaring heritage	Local experience with sailing; waning knowledge
Auxiliary propulsion	Retrofit / New Build	Solar irradiance	Suva average = 3.69 to 6.35 $kWh/m^2/day$**	N/A	Lack of experience and technical know-how with solar PV (only limited application with lighting)
1st generation	Retrofit / New Build	Coconut oil	Copra oil net calorific value = 37,100 kJ/kg (compared with fuel oil NCV = 41,900 kJ/kg)***	Vatoa copra production	Main commodity of Vatoa is copra; would require significant upscale in production

* Statistics for Ono-i-Lau (https://www.windfinder.com/windstatistics/ono-i-lau); general note: SE trade winds make return journey to Suva more suitable for wind applications; however, variability in seasonal wind patterns require actual trails of regular transport to determine suitability of wind applications
** Statistics for PV in Suva (http://www.solarelectricityhandbook.com/solar-irradiance.html); actual sea route and daily fluctuations likely vary considerably
*** Courty, Vaïtilingom, &Liennard, 2000

Despite the significant challenges that remain to develop the lower southern Lau route as a sustainable sea transport model for the region, activating these potentials together with proper financing, partnerships, and cooperation can result in a successful endeavor. An example of the benefits to the local economy can be seen from the study on copra biofuel, in which 68% of the cost of coconut oil electricity returns to the village economy as opposed to only 5% for ADO electricity (Courty, Vaïtilingom, &Liennard, 2000). Clearly, investing in the time, money, and resources that activate these local potentials in a sustainable manner will pay dividends in the long run.[11]

[11] For other useful overviews on copra and coconut oil production, see Jan Cloin's report on "Coconut oil as a biofuel in Pacific islands – challenges and opportunities" (http://ict.sopac.org/VirLib/MR0592.pdf) and Australia's engineers without borders "coconut as a biofuel" site (http://www.ewb.org.au/resources/52/950).

6.2 Increasing system efficiency

The status quo method of sea transport to the lower southern Lau islands has tremendous opportunity for increasing overall efficiency. The field study reveals the inefficiencies of the current transport system – namely, engineering and operational. This section explores the possible efficiency improvements that renewable energy technologies, in a general sense, can bring to this route.

Inefficiencies in the engineering systems and operations of the actual cargo and passenger transfer result in wasteful fuel consumption, potential monetary loss, and schedule delays. An illustration of the engineering inefficiencies is the early 2014 engine casualty, when *MV Liahona* was operating its other monthly route to the northern Lau islands.This casualty aboard *MV Liahona* took the ship out of service for several months and required the government to provide shipping services along both the northern and lower southern Lau routes in the interim. Since then, the main engine has been upgraded to a newer Cummins KTA19-M3-600 and a more efficient Cummins 6BT 5.9-GM83 (65kVA) installed as well. However, these are merely expedient measures that do not necessarily result in improved overall efficiency, nor do they tackle the underlying issue of dependency on fuel imports and the negative externalities on the environment.

Likewise, the operations of cargo and passenger transfer require extensive manpower and time. Retrofitting *MV Liahona*with a more accessible cargo hold or beach landing capability is highly unrealistic; however, replacing it with a new build vessel such as the Greenheart Project design would likely result in significant gains in operational efficiency.The Greenheart Project concept is to have a zero-emissions vessel with easy transfer operations using a low stern gate to better accommodate cargo handling

(Greenheart Project, 2015). A future study that comprises a thorough cost-benefit analysis of such efficiency issues is necessary to determine the overall effect of developing a sustainable sea transport system for this route.

6.3 Decreasing operating costs

One of the main barriers to profitable shipping services is due to the operating costs. As the field study revealed, the antiquated freight rate and high relative cost of fuel together with the typically low volume of cargo and passengers all factor into the necessity for the shipping franchise scheme. If a high investment is required to ensure an economically viable and sustainable sea transport system, the possibility of a long term reduction in operating costs could entice the key stakeholders to pool their resources in order to implement such a system.

First, the finances of the entire shipping service to the lower southern Lau islands rely on government subsidies to operate without a continual deficit that could require a significant increase in freight rate or passenger fares. As noted in Appendix 4, the government provided 216,000 FJD in shipping subsidies under the GSFS for the entirety of 2014. The net revenue over the same period was 251,909 FJD. Assuming the March 2015 fuel price as an average for 2014, then 115,560 FJD – or 45.87% – of the 251,909 FJD annual revenue goes toward fuel costs alone. This leaves 136,349 FJD per year for all remaining costs. These remaining costs are unknown in this study, since no information regarding employee salary, operations and maintenance costs, or other miscellaneous expenditures were made available. However, from the interview with Mr. Baivatu, around 25 employees work for South Island Shipping Services. If the remaining revenue alone goes to employee salary, this leaves an average of 5,453.96 FJD per annum for each employee. This is 16.64% lower than the average adult income in the Central Region urban area, which was

6,543 FJD/a in 2008-2009 (Fiji Bureau of Statistics, 2014, 145). Although this is a basic analysis of the financial aspects of this business, it is evident that without the additional 216,000 FJD in government subsidies, South Island Shipping Services would not be able to operate profitably a route to the lower southern Lau islands.

All else being equal, if the variable of fuel cost changes due to the implementation of renewable energy technologies, then significant cost savings can be realized. Table 6.2 shows potential savings and CO_2 emissions reductions from data gathered in Chapter 5. This does not account for the probability of increasing fuel prices, nor does it provide any definitive basis for determining if the initial investment in such technologies will be profitable. However, it clearly shows that in the long run, applying innovative renewable energy sea transport systems for the lower southern Lau route – especially with the right financing tools such as credits for GHG reduction – have potential for decreased operational costs.

Table 6.2: Potential savings and CO_2 emissions reductions from renewable systems (Author, 2016)

	Unit/ year	Current estimate	Future estimates of reductions in fuel consumption using renewable energy technologies			
			25%	50%	75%	100%
Subsidy	*FJD*	216,000	216,000	216,000	216,000	216,000
Revenue	*FJD*	251,909	251,909	251,909	251,909	251,909
Fuel Cost	*FJD*	115,560	86,670	57,780	28,890	-
Potential savings	*FJD*	-	28,890	57,780	86,670	115,560
CO_2 emissions	*kg CO_2*	193,898.88	145,424	96,949	48,475	-

Despite the probable investment cost being moderately high for retrofitting *MV Liahona* and significantly high for a new build replacement, the summation of the annual operational costs over the lifetime service create an incentive to owners and operators.

6.4 Creation of stakeholder network

Critical to the success of any project such as this is the establishment of a cohesive stakeholder network unified to achieve a common goal. Indeed, while the underlying motivations and interests are different for each stakeholder, only by joining together and supporting the common aim of a sustainable sea transport route can their individual aspirations be realized. Section 5.2.5 postulates the key stakeholders necessary to ensuring the success of this endeavor, and their individual interests are formulated in Table 5.11. Beyond the key stakeholders, various other government agencies, research and academic centers, business organizations, and community members must be included in the full stakeholder network. A demonstrative depiction of a theoretical network is shown in Figure 6.1, although realistically the network is much more expansive and likely to grow over the development of the project.

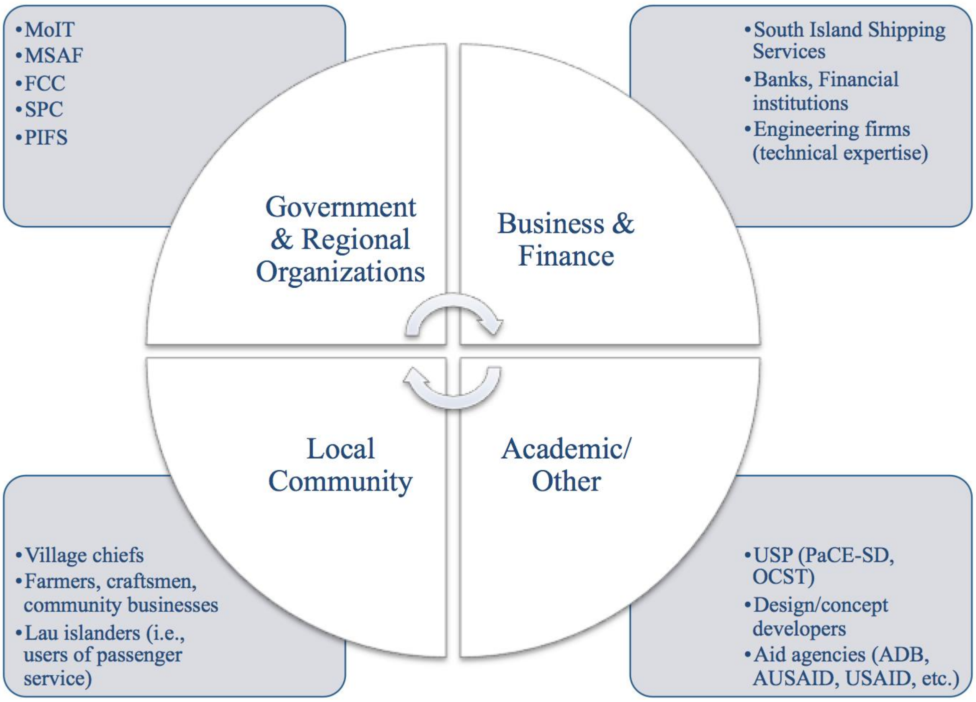

Figure 6.1: Stakeholder network for lower southern Lau route (Author, 2016)

Despite the inchoate stakeholder network as depicted inFigure 6.1, the invaluable necessity of a comprehensive, functional and flexible stakeholder network cannot be overstated. The technical expertise of professional engineers, financial instruments provided by international donors and regional organizations, business acumen of shipping operators, and social influence of village chiefs all contribute their part to the synergy of bringing to fruition a sustainable sea transport route and, subsequently, national and regional system.

6.5 Creation and maintenance of jobs

Another important aim of MFM is to ensure that the project is sustainable for the local economy by not only maintaining jobs, but creating new opportunities for employment as well. Rather than introducing a new sea transport model that includes automation and advanced technologies with minimal human involvement, the best scenario for this particular route – and perhaps to all domestic sea routes of SIDS – is one that optimizes the employment opportunities. Proper projections and development of this factor requires a thorough demographic analysis of the islands in questions. Relevant knowledge includes population growth/decline rates, age and education levels, and average income and economic statistics of the Lau islands.

The minimum employment requirement for a sustainable sea transport route is that the number of jobs does not diminish. In particular, the approximately 25 employees working for South Island Shipping Services must have readily transferrable skillsets that match jobs on the retrofit vessel or new build design. In this case, even if profit can be increased due to the application of new, clean technologies, if fewer jobs are required then the result would be an overall detriment to the shipping sector. At a time of increasing youth and more competitive job seeking, a cleaner shipping route is not socially sustainable if the end result is a reduction in employment opportunities.

An even more positive scenario is one in which the overall result is job creation. If fuel costs are significantly reduced or eliminated through the implementation of renewable energy technologies, then perhaps a slightly larger crew may benecessary for enhanced operational necessities (e.g., capable and knowledgeable sailor and engineers). In this case, the aim is for the project to create or maintain jobs without concomitant fare or freight rate increases. The best project will attend to the passenger considerations, paying attention to the survey results from Table 5.10 in which lower cost and greater comfort is preferable. This balance of maintaining or creating jobs for the shipping service while reducing fares and improving passenger comfort will produce the most salient project for a sustainable sea transport route.

6.6 Support innovative SMEs

In line with the previous aim of job creation, a sustainable sea transport initiative is readily able to support innovative small/medium enterprises (SMEs). In the case of retrofitting a vessel such as *MV Liahona* with soft sails and solar panels, a host of SMEs can benefit. Import and procurement enterprises specializing in renewable energy technologies such as solar can supply the necessary material requirement, design firms can create the blueprints and technical drawings, and engineering firms can conduct the actual installation procedures.

In the case of a new build vessel, with the proper incentives and financial schemes in place, local shipbuilders can engage in the actual construction of the new vessel. Of course, one must compare foreign shipbuilders and conduct a total cost/benefit analysis to determine the viability of a local build. However, in line with the aim of MFM, even if the total investment in a local build exceeds the costs of contracting a foreign shipbuilding company, Fiji could benefit in a variety of ways by keeping the contract local. The idea is to add jobs to the local economy, enhance the skillsets of local shipwrights, and create a viable, replicable platform for future builds.

Additionally, a sustainable sea transport project has potential to support other SMEs along the supply chain and shipping route. One example is the development of the copra business on Vatoa. If there is the capacity and capability to provide a biofuel or blend from coconut oil, supplying a vessel that can accept this fuel mix is an interesting possibility. The shipping service provider can enter into a direct supply contract with the village of Vatoa, and it can support the development of manufacturing facilities either in Vatoa or Suva to process the copra into an acceptable fuel. Similarly, the traditional shipbuilders of Kabara can revive their dwindling shipwright economy such as they did in the 1980s with the construction of the *Tai Kabara*. In this sense, a sustainable sea transport initiative is particularly well suited for the lower southern Lau islands.

6.7 Creation of sustainable economy and society

Findings from thisresearch and the field study of the lower southern Lau islands lead to the seventh and final, overarching aim of MFM – the creation of a sustainable economy and society. Indeed a sustainable sea route cannot be termed as such if the economic and social aspects are not fully intertwined. Sections 6.1 through 6.6 together make the foundation for this final aim. In line with the idiom that the first step is always the most difficult, the initial barriers to implement a clean sea route for Fiji are merely hurdles that must be overcome. These initial challenges in the form of sufficient finances and investment, technical ability and local opportunity can be overcome through the implementation of an MFM master plan. Again, the key component to realizing success is to ensure the key stakeholders are properly engaged and the overall stakeholder network is built with a strong support base. Only then can all other pieces join together.

7 Conclusion: Plotting a new course

Reaching the terminus of this thesis, EpeliHau'ofa'ssalient quote upon which this voyage began now resonates more clearly than ever. The sea is the irrefutable pathway that links Pacific islanders; it is the source and vitality of our planet and – more pronounced than anywhere else – the people of Oceania. What began as the proverbial gut feeling regarding the tremendous devastation wreaked by mankind on this planet morphed into this pursuit of advanced understanding of sustainable development issues. The deep passion for seafaring cultures and compassion for conserving nature and traditions, together with an interest in advanced applications of clean technologies, shaped the research into this ontological study of the lower southern Lau route and potentials for creating a model of sustainable sea transport. While this thesis has not implemented any actual project or solutions, it has added to the body of knowledge regarding sustainable sea transport and propels the opportunities for future studies.

This thesis provides a foundation for the adaptation of the Material Flow Management (MFM) model to the small island states of the Pacific. While this methodology and approach has suited eco-efficient initiatives in Germany for over two decades, tailoring it to small island communities has particular challenges and opportunities. The small population size, lower technological and industrial economic bases, and geographical constraints require unique strategies to adapt MFM to this environment. The opportunities, however, are unequivocally ripe for reviving sea transport in a manner suitable to the traditional seafaring heritage and the prolific development of modern, clean technologies. Thus, this thesis offers an expedient method that grasps the potential of the lower southern Lau routes. Indeed, if the most remote, uneconomical route in Fiji can realize a sustainable solution, the model can be replicated throughout the region.

7.1 Limitations of the study

During the course of writing this thesis, various limitations arose, posing as challenges to adapt to or overcome.First and foremost, limited field study time on the lower southern Lau route did not lend ample support to develop substantial experiential knowledge and data. Only one field study was taken, in March 2015, and thus all other monthly voyages have to be considered as producing similar results. Of course, each voyage has their unique aspects, thus the possibilities of various fuel consumption levels, profit margins, and passenger satisfaction surveys are leveled here into one common scenario. An ideal study would span the course of one year, taking into account seasonal fluctuations and other variables.

Furthermore, the field study did not have the means available to fully collect and analyze more relevant scientific data. Average wind speeds and patterns, copra production, exact volume and weight of cargo and passengers, solar irradiance, and other essential data would be most beneficial if collected on site over the course of one year. Another major limitation is the analysis of social aspects, such as a compendium of seafaring and shipwright knowledge of the Lau islanders, the willingness to revitalize this heritage, and the acceptability of sustainable shipping solutions to the shipping company, government, and islanders. Of course, the limited scope of study cannot capture all of this data, but it has potential for a more advanced doctoral dissertation or comprehensive scientific study.

Additionally, the design of this study investigates one chosen model of eco-efficiency – MFM – that may or may not result in the most suitable sustainable shipping solution for this particular route. This is a management approach that explores innovative technologies to improve the eco-efficiency of one particular sector, but it does not exclude the possibility of alternate methods producing similar or better results.Limiting the scope of study within the bounds of MFM to produce a sustainable sea transport model reflects the master's degree coursework and associated requirements. The implications of this thesis, however, suggest that the framework and methodology can yield an appropriate model for future replication.

7.2 Proposals for future research

This thesis augments the growing body of literature pertaining to sustainable sea transport. With a specific, limited scope, it captures the most uneconomical domestic shipping route in Fiji, analyzes the current situation, and offers one potential model for future academic or real-world projects. In a sense, it is a springboard built upon previous scientific inquiries that can launch more comprehensive studies.

To expound upon this case study, the limitations mentioned earlier could be properly accounted for, leading to prospective in-depth analyses of the lower southern Lau – or similar – sea routes. A more long term, controlled study that truly collects and analyzes the cargo and passenger flows to each individual island, the vessel performance, and weather and climate data is one possible direction of research. Alternatively, replicating this model for a comprehensive, interwoven sustainable sea network in Fiji or the broader region could yield interesting, informative results. In any case, this thesis provides a platform for developing a more comprehensive study of MFM for sustainable sea transport based on accurate measurements of all essential data.

Every step on the path of sustainability – however small – is a step to benefit mankind and our natural environment. In the hopes of bridging island closer together and calming the tumultuous seas of the changing times, let us strengthen the collective *ocean in us*.

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Appendix 1: Domestic shipping data - uneconomical routes (April 2013 – April 2014)

Route no.	Sea routes	Total mileage (nm/voyage)	Current subsidy (FJD/voyage) *(FJD/nm)*	Islands serviced	Total pop. served	Ship contracted	Ship capacity (DWT)	Total cargo flows (tons/year)		Total passenger flows (persons/year)	
								IN	OUT	IN	OUT
1	Northern Lau I	201	7,500 *(37.30)*	Vanua balavu, Cicia	2,823	Lomaiviti II	1039	142	305	336	552
2	Northern Lau II	396	15,000 *(37.90)*	Lakeba, Nayau, Yacata, Tuvuca, Cikobia	2,268	Liahona	197	253	154	483	457
3	Upper Southern Lau	417	14,000 *(33.60)*	Vanuavatu, Lakeba, Oneata, Moce, Komo, Namuka	3,097	Lady Sandy	400	343	415	1128	1479
4	**Lower Southern Lau**	**416***	**18,000** ***(34.90)***	**Kabara, Fulaga, Ogea, Vatoa, Ono-i-Lau**	**1,537**	**Liahona**	**197**	**210**	**221**	**619**	**584**
5	YasayasaMoala	281	12,000 *(42.70)*	Moala, Matuku, Totoya	2,594	Lady Sandy	400	274	381	1039	1072
6	Rotuma	822	25,000 *(30.40)*	Rotuma	2,002	Lady Sandy	400	139	348	807	989
7	Kadavu (Babaceva)	118	10,000 *(84.70)*	Muani, Galoa, Dravuwalu, Soso, Vukavu, Vacalea, Nukuvou, Matasawalevu	3,698	Uluinabukelevu	120	106	210	284	370
8	Lomaiviti I	140	8,000 *(57.10)*	Nawaikama, Gau	2,385	Uluinabukelevu	120	273	278	361	738
9	Lomaiviti 2	140	7,500 *(53.60)*	Nairai, Batiki, Gau	3,470	Uluinabukelevu	120	127	156	604	945
10	Yasawa- Malolo	183	8,000 *(43.70)*	MatacawaLevu, Yaqeta, Viwa, Naviti, Yasawa, Waya, Nacula	3,650	YII	20	28	65	82	200
TOTAL		**3214/voyage**	***125,000/voyage***		**27,524**	**5 vessels**		**1,895**	**2,533**	**5,743**	**7,386**

NOTE: Subsidies in FJD/nm are provided by MWTPU, 2014. These numbers do not necessarily equate to NM/voyage (column 3) divided by current subsidy of FJD/voyage (column 4).
* 416 nautical mile distance is determined from Fiji nautical chart on board *MV Liahon*; this does not match the 2014 report from MWTPU that states a round trip distance of 516 nautical miles

Appendix 2: Uneconomical route cargo/pax flows, 2014

			Cargo (tons)		**Pax (number)**					**Cargo (tons)**		**Pax (number)**	
			In	**Out**	**In**	**Out**				**In**	**Out**	**In**	**Out**
	1	USL	40	35	173	65		1	USL	20	60	89	80
	2	YyM	40	30	191	81		2	YyM	12	18	58	44
	3	LSL	17	5	68	52		3	LSL	15	22	23	19
	4	NLI	*	*	*	*		4	NLI	30	25	27	32
January	5	NLII	40	10	30	57	July	5	NLII	35	17	89	23
	6	LI	40	30	40	74		6	LI	9	13	48	36
	7	LII	30	40	105	98		7	LII	2	12	6	24
	8	K	34	50	3	4		8	K	10	5	35	23
	9	R	20	30	118	128		9	R	30	25	15	10
	10	YM	4	4	12	14		10	YM	0***	5	2	16
Month total			265	234	740	573	Month total			163**	202	392	307
	1	USL	15	32	86	122		1	USL	60	40	200	85
	2	YyM	17	40	60	170		2	YyM	60	40	189	56
	3	LSL	54	40	40	110		3	LSL	25	30	30	76
	4	NLI	*	*	*	*		4	NLI	10	13	33	147
February	5	NLII	*	*	*	*	August	5	NLII	13	8	5	6
	6	LI	16	21	25	56		6	LI	20	25	20	101
	7	LII	18	8	36	91		7	LII	8	10	225	38
	8	K	12	16	30	16		8	K	12	20	101	83
	9	R	22	35	73	55		9	R	110	35	67	57
	10	YM	1	4	4	15		10	YM	1	5	1	16
Month total			155	196	354**	635	Month total			319	226	871	665
	1	USL	37	46	156	158		1	USL	40	80	49	170
	2	YyM	25	17	59	53		2	YyM	70	60	39	215
	3	LSL	4	9	16	14		3	LSL	10	26	34	19
	4	NLI	42	135	119	90		4	NLI	20	35	41	38
March	5	NLII	17	12	24	16	September	5	NLII	20	15	15	14
	6	LI	40	20	13	7		6	LI	16	30	60	100
	7	LII	2	4	27	65		7	LII	110	135	32	250
	8	K	12	18	22	17		8	K	2	23	16	35
	9	R	20	30	48	65		9	R	12	32	16	85
	10	YM	1	6	5	19		10	YM	2	5	11	19
Month total			200	297	489	504	Month total			302	441	313	945
	1	USL	50	60	70	176		1	USL	53	134	20	40
	2	YyM	30	17	41	31		2	YyM	35	30	67	85
	3	LSL	20	18	25	31		3	LSL	20	30	30	42
	4	NLI	40	60	66	163		4	NLI	30	45	122	137
April	5	NLII	16	17	23	19	October	5	NLII	18	25	34	19
	6	LI	15	16	34	48		6	LI	7	21	19	38
	7	LII	7	10	85	51		7	LII	25	9	53	15
	8	K	5	11	18	43		8	K	5	20	28	31
	9	R	5	40	17	95		9	R	35	50	159	150
	10	YM	0	4	2	17		10	YM	1	8	10	13
Month total			188	253	381	674	Month total			229**	372	542	570**
	1	USL	15	120	35	117		1	USL	35	65	203	189
	2	YyM	12	42	29	105		2	YyM	30	40	98	63
	3	LSL	5	8	26	21		3	LSL	25	32	61	48
	4	NLI	56	58	48	75		4	NLI	18	6	56	79
May	5	NLII	20	18	10	11	November	5	NLII	15	25	15	30
	6	LI	8	18	27	37		6	LI	18	20	23	77
	7	LII	7	12	32	100		7	LII	10	30	18	35
	8	K	18	22	18	23		8	K	8	21	36	27
	9	R	30	35	47	60		9	R	3	30	33	227
	10	YM	2	10	7	18		10	YM	2	16	22	19
Month total			173	343	279	567	Month total			164	285	565	794
	1	USL	40	70	62	99		1	USL	70	70	179	445
	2	YyM	50	30	19	72		2	YyM	40	35	248	130
	3	LSL	25	15	48	22		3	LSL	30	40	79	131
	4	NLI	60	90	100	80		4	NLI	120	125	86	289
June	5	NLII	20	45	32	45	December	5	NLII	14	21	41	30
	6	LI	22	20	56	57		6	LI	11	8	63	44
	7	LII	50	40	100	98		7	LII	10	11	130	136
	8	K	5	12	18	36		8	K	5	26	42	39
	9	R	7	60	84	112		9	R	25	10	170	9
	10	YM	1	8	2	12		10	YM	0.5	5	5	36
Month total			280	390	521	633	Month total			325.5**	351**	1043**	1289**
1st half subtotal			1261	1713	2764	3586	2nd half subtotal			1502.5	1877	3726	4570
							2014 TOTAL			**2763.5**	**3590**	**6490**	**8156**

*Route was not serviced
**Inconsistent data from MoIT 2014 Annual Report
***Recorded as 20kg in master spreadsheet; here rounded down to 0
NOTE: See Table 5.2 for the shipping route codes (e.g., LSL = Lower Southern Lau, etc.)

Appendix 3: Uneconomical route financial flows, 2014

Month	No.	Route	Cargo revenue (FJD) In	Cargo revenue (FJD) Out	Pax revenue (FJD) In	Pax revenue (FJD) Out	GSFS payment (FJD)
January	1	USL	16655	14845.55	18210	8125	14000
	2	YyM	18420	16655.5	15755	7055	12000
	3	LSL	312	102	3133	2430	18000
	4	NLI	*	*	*	*	*
	5	NLII	0	0	1283.1	2511.6	15000
	6	LI	526	2000	1380	2900	8000
	7	LII	524	4025	5565	5100	7500
	8	K	1635	3510	4705	1830	10000
	9	R	14895	18450	19500	22200	25000
	10	YM	200	350	391	598	8000
Month total			53167	59938.05	69922.1	52749.6	117500
February	1	USL	3709.33	9546.48	1050	2880	14000
	2	YyM	1420	6562	6050	17650	12000
	3	LSL	425	1391.9	1119.43	3512.2	18000
	4	NLI	*	*	*	*	7500
	5	NLII	*	*	*	*	15000
	6	LI	8525	9246.5	1625	3640	8000
	7	LII	800	1252	2100	4870	7500
	8	K	1860	3680	1800	960	9583
	9	R	823	5344	13065	8900	25000
	10	YM	0	228	184	230	8000
Month total			17562.33	37250.88	26993.43	42642.2	124583
March	1	USL	526	8047	18000	17125	14000
	2	YyM	1203	923	6195	5565	12000
	3	LSL	950	519	2125	2036	18000
	4	NLI	3709	15546	3050	2880	7500
	5	NLII	1129.64	4806.13	1365	2160	15000
	6	LI	715	2131	840	420	8000
	7	LII	1345	1700	1305	3400	7500
	8	K	1508	2320.6	1430	1105	10000
	9	R	11650.5	15400	8640	11700	25000
	10	YM	0	1228	575	950	8000
Month total			22736.14	52620.73	43525	47341	125000
April	1	USL	12655	21760.55	7500	20330	14000
	2	YyM	16455	14352.55	2865	3805	12000
	3	LSL	9125	10427	4124	5115	18000
	4	NLI	1322	5566	10560	26080	7500
	5	NLII	3872	875	2235	1613	15000
	6	LI	923	1112	2380	3360	8000
	7	LII	324	1112	5525	3315	7500
	8	K	1670	3140	910	2410	10000
	9	R	960	6636	3315	18525	25000
	10	YM	800	**	2	96	8000
Month total			48106	64981.1	39416	84649	125000
May	1	USL	945	7497	3550	12375	14000
	2	YyM	672	2296	2550	9540	12000
	3	LSL	950	6115	25125	2036	18000
	4	NLI	524	4025	6480	7875	7500
	5	NLII	10455	9547	1350	1485	15000
	6	LI	7525	9147	1890	2590	8000
	7	LII	2115	6700	2240	7000	7500
	8	K	975	2320.6	1260	1610	10000
	9	R	1523	2356	9165	11700	25000
	10	YM	715	523	80	225	8000
Month total			26399	50526.6	53690	56436	125000
June	1	USL	1675	5323	7750	12375	14000
	2	YyM	3300	1325	9450	7560	12000
	3	LSL	2050	1250	6805	3195	18000
	4	NLI	2676	6844	12500	10000	7500
	5	NLII	645	895	645	956	15000
	6	LI	2560	5680	3640	3705	8000
	7	LII	524	1025	5565	5100	7500
	8	K	1670	3140	910	2410	10000
	9	R	5549	7054	2115	6700	25000
	10	YM	10	57	92	442	8000
Month total			20659	32593	49472	52443	125000
1st half subtotal			188629.47	297910.36	283018.53	336260.8	742083

Month	No.	Route	Cargo revenue (FJD) In	Cargo revenue (FJD) Out	Pax revenue (FJD) In	Pax revenue (FJD) Out	GSFS payment (FJD)
July	1	USL	1050	2880	3709	9546	14000
	2	YyM	950	525	4620	6090	12000
	3	LSL	950	6115	2125	2036	18000
	4	NLI	4500	5000	60500	6100	7500
	5	NLII	3872	1075	2235	1613	15000
	6	LI	223	3115	2120	2880	8000
	7	LII	245	1122	480	1920	7500
	8	K	1670	3140	3010	2320	10000
	9	R	2000	3000	2440	4250	25000
	10	YM	92	800	20	800	8000
Month total			15552	26772	81259	37555	125000
August	1	USL	3855	2600	15900	8100	14000
	2	YyM	18230	13450	15545	4680	12000
	3	LSL	1020	1450	4800	12160	18000
	4	NLI	554	3315	5280	23520	7500
	5	NLII	865	1250	675	810	15000
	6	LI	894	3051	1400	7070	8000
	7	LII	1252	820	14625	2660	7500
	8	K	835	2015	6060	4980	10000
	9	R	3323	10656	11400	13400	25000
	10	YM	25	323	50	800	8000
Month total			30853	38930	75735	78180	125000
September	1	USL	2800	3850.6	5620	17600	14000
	2	YyM	1140	4856	3670	17075	12000
	3	LSL	950	4115	2565	4215	18000
	4	NLI	992	3153	6750	5940	7500
	5	NLII	2235	980	2025	1890	15000
	6	LI	850.5	1155.6	3900	6500	8000
	7	LII	2202	3439	300	11400	7500
	8	K	890	4120	1120	2410	10000
	9	R	861	4210	1120	1340	25000
	10	YM	11	46	450	800	8000
Month total			12931.5	29925.2	27520	69170	125000
October	1	USL	16750	3323	625	16750	14000
	2	YyM	3300	1325	7035	9030	12000
	3	LSL	1010	3450	4800	6720	18000
	4	NLI	8500	11092**	14520	16645	7500
	5	NLII	725	5204	4590	3240	15000
	6	LI	823	5012	1425	2850	8000
	7	LII	354	5686	1120	3710	7500
	8	K	235	2015	1680	1860	10000
	9	R	2566	6656	28055	29250	25000
	10	YM	10	51	70	210	8000
Month total			34273	43814	63920	90265	125000
November	1	USL	1675	5323	22005	22465	14000
	2	YyM	8560	12450	8090	6015	12000
	3	LSL	9560	10250	10065	7920	18000
	4	NLI	1900	4200	7560	10665	7500
	5	NLII	966	1015	2025	4050	15000
	6	LI	655	2105	1795	5005	8000
	7	LII	250.5	2885.5	1260	2450	7500
	8	K	955	2605	2025	2700	10000
	9	R	323	11099**	6600	45400	25000
	10	YM	100	1356	990	855	8000
Month total			24944.5	53288.5	62415	107525	125000
December	1	USL	2420	4320	23435	57515	14000
	2	YyM	13650	26040	26040	13650	12000
	3	LSL	9850	18560	12165	20685	18000
	4	NLI	7580	11466	42960	12580	7500
	5	NLII	950	1865	5535	4050	15000
	6	LI	1054	986	3300	4725	8000
	7	LII	1860	2300	8450	8840	7500
	8	K	1020	3420	3150	2925	10000
	9	R	6500	3520	33150	1755	25000
	10	YM	40	1275	276	2131	8000
Month total			44924	73752	158461	128856	125000
2nd half subtotal			163478	266481.7	469310	511551	750000
2014 TOTAL			**352107.47**	**564392.06**	**752328.53**	**847811.8**	**1492083**
2014 TOTAL REVENUE					**4,008,722.86**		

NOTE: See Table 5.2 for the shipping route codes (e.g., LSL = Lower Southern Lau, etc.)

* Route was not serviced

** Data inconsistency as recorded on master spreadsheet; estimated to most feasible whole number

Appendix 4: Consolidated lower southern Lau route data, 2014

Lower southern Lau route voyage	Current subsidy (FJD)	Ship contracted	Total cargo flows (DWT/month)		Total passengersflows (persons/month)		Cargo payment (FJD/month)		Passenger payment (FJD/month)	
			In	Out	In	Out	In	Out	In	Out
January	18,000	Rogovoka	17	5	68	52	312	102	3133	2430
February	18,000	Boilovatu	54	40	40	110	425	1391.9	1119.43	3512.2
March	18,000	Liahona	4	9	16	14	950	519	2125	2036
April	18,000	Liahona	20	18	25	31	9125	10427	4124	5115
May	18,000	Liahona	5	8	26	21	950	6115	25125	2036
June	18,000	Liahona	25	15	48	22	2050	1250	6805	3195
July	18,000	Liahona	15	22	23	19	950	6115	2125	2036
August	18,000	Liahona	25	30	30	76	1020	1450	4800	12160
September	18,000	Liahona	10	26	34	19	950	4115	2565	4215
October	18,000	Liahona	20	30	30	42	1010	3450	4800	6720
November	18,000	Liahona	25	32	61	48	9560	10250	10065	7920
December	18,000	Liahona	30	40	79	131	9850	18560	12165	20685
Total Subsidy:	**216,000**		250	275	480	585	37,152	63,745	78,951	72,060
							Net Revenue (excluding GSFS)		**251,909**	

Data compiled by author from master spreadsheet of Transport Planning Unit, Fiji Ministry of Infrastructure and Transport

Appendix 5: Shipping operator interview question

Name: Mr. Baivatu, Ulaiasi

Company: South Island Shipping Services

Date: 19 March 2015

1. What factors motivated you to purchase and operate *MV Liahona*? What factors motivated you to operate the lower southern Lau route?
2. How many employees work for South Island Shipping Services?
3. What are the most significant barriers and challenges to ensure a successful operation in support of the shipping route?
4. What influences your decisions on scheduling and operation of the lower southern Lau route? (e.g., fuel prices, weather, community requests, etc.)
5. Is the GSFS sufficient to ensure a profitable operation?
6. Would you continue to operate the lower southern Lau route if the GSFS stopped?
7. If you could change the GSFS or other government regulations, what would be your recommendation? (e.g., increase/decrease subsidization, promote greater economic competition through various incentives, etc.)
8. What are your thoughts on using renewable energy technology for sea transportation? (e.g., retrofitting *MV Liahona* with fixed-sails or soft-sails, adding PV panels on the weather decks to augment auxiliary power, purchasing a zero/low-emissions vessel/engine, etc.)
9. In your opinion, what external factors can contribute the most to improving domestic sea transport for Fiji’s uneconomical routes?
10. What is your vision for the future of domestic sea transportation among the Fiji islands?

Appendix 6: Route passenger questionnaire

Questionnaire:

1. What island do you consider your primary residence?
2. What is your occupation?
3. What is the purpose of your voyage?
4. What is your final destination?
5. How long do you intend to stay at your final destination before returning to your primary residence?
6. How often do you embark on the interisland transport?
7. On a scale of 1 to 5, (1 being very unsatisfied and 5 being very satisfied) please rate the following:

Survey:	1 Very Unsatisfied	2 Unsatisfied	3 Average	4 Satisfied	5 Very Satisfied	N/A Not Applicable
Cost						
Comfort						
Duration						
Scheduling						

Comments: