POSSIBILITIES FOR CHANGE - INCORPORATING TECHNOLOGY POLICY AND ANALYSIS OF STAKEHOLDER PREFERENCES INTO THE ENVIRONMENTAL POLICY FRAMEWORK FOR REDUCING AIR EMISSIONS FROM CONTAINERIZED SUPPLY CHAINS

by

Melissa A. Woehl

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment
of the requirements for the degree of Master of Marine Policy

Summer 2011

POSSIBILITIES FOR CHANGE - INCORPORATING TECHNOLOGY POLICY AND ANALYSIS OF STAKEHOLDER PREFERENCES INTO THE ENVIRONMENTAL POLICY FRAMEWORK FOR REDUCING AIR EMISSIONS FROM CONTAINERIZED SUPPLY CHAINS

by
Melissa A. Woehl

Approved: ____
James J. Corbett, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____
Charles E. Epifanio, Ph.D.
Director of the School of Marine Science and Policy

Approved: ____
Nancy M. Targett, Ph.D.
Dean of the College of Earth, Ocean, and Environment

Approved: ____
Charles G. Riordan, Ph.D.
Vice Provost for Graduate and Professional Education

ACKNOWLEDGMENTS

I would like to acknowledge both my family and my committee members for their support and guidance through this process. Most especially, I would like to recognize my husband Scott, whose patience, counsel, and sense of humor were a foundation that I could always draw from throughout this adventure. I would also like to thank the industry leaders who participated in this work for their willingness to share their experience, knowledge, and candid responses.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This research, through a detailed assessment of the vessel emissions issue and the containerized shipping segment, examines the environmental policy-making framework within the area of international maritime shipping. It evaluates current approaches and methods being used and investigates whether or not alterations could be made to improve the current policy-making process for environmental issues. Specifically, this work probes whether or not the incorporation of concepts from technology policy and decision theory, explicitly through tools designed to identify stakeholder values, could provide new insights to or approaches for environmental policy-making within the international marine transportation system. The study then provides direction as to how these elements might be integrated with the current structure.

An industry born from and controlled by the supply and demand requirements of growing domestic and global economies, international marine transportation has a reputation of fierce internal competition. This characteristic rewards forward thinking and has led to a focus on technological change and innovation for advancement. Unlike many land-based industries, though, international marine transportation has been able to continue to drive its development - from a regulatory standpoint - in a uniquely independent manner due to its distinctive situation as a business where every nation has a stake but no one has ultimate control [1-6].

Knowledge regarding the harmful effects and sources of various air pollutants such as nitrogen oxides, sulfur oxides, and particulate matter grew through focused research during the 1970's and 1980's, but recognition and examination of the global contributions and impacts from ocean-going commercial marine vessels did not occur until the 1990's. Since that time, international and domestic organizations have devoted time, resources, and research to identify, measure, and understand the impacts of the vessel emissions issue. Based on the results of that work, regulations and agreements were implemented across multiple levels – local, regional, domestic, and international. These initiatives, however, especially at the domestic and international levels, are slow-moving and tend to predominantly focus on certain participant groups, discouraging communication and coordination among all of the stakeholders [1-11].

This work proposes a shift or transition in attention and research towards the process – towards studying ways to specifically improve and expand the environmental policy-making framework – and contends that process-focused developments serve as an effective means for supporting and facilitating continuous improvements in the reduction of vessel emissions. Due to a combination of specific operational and geographic attributes (which will be discussed in greater detail in the next chapter), the containerized shipping segment serves as the most critical target within the international shipping industry for this issue. Vessel air emissions is certainly not the only environmental problem, and the container industry is not the only segment of the international shipping community, but the method of approaching environmental issues within the marine transportation system (MTS) has become a somewhat standardized process across problems and industry sectors, making the conclusions from this work readily applicable to other environmental issues and segments within the global maritime system.

Chapter 1

INTRODUCTION TO RESEARCH

1.1 Motivation for Research

Carrying the responsibility for moving the materials and goods that fuel our daily lives, transportation networks are the critical, but often unrecognized, lifelines that facilitate our continued domestic and global economic growth. This work looks at the impacts of one of the most groundbreaking advancements in the international transportation network – containerization. Containerization has revolutionized the marine transport system and, despite the significant negative impacts to the industry from the global recession in 2009, remains the fastest growing maritime trade sector both in wealth and in volume. Without it, the standardized, consistent, and reliable network of global supply chains that businesses have come to rely on to maintain operations and facilitate continued expansion would not be possible [12-15]. The impacts created by this sector are far-reaching, and, as with other thriving businesses, addressing the negative effects becomes as important as celebrating the positive ones.

The need to better address environmental problems is now a recognized and established concept in the maritime field. This work explores one of the industry's most intensely debated environmental topics – the negative impacts from marine vessel emissions. As the body of research aimed at defining and understanding the intensity and severity of environmental and health effects from vessel emissions grew, the maritime world faced increasing pressure from both domestic and international regulatory agencies, non-governmental organizations (NGO's), and other industry participants to reduce the negative air quality impacts from its operations [2, 16-23]. This attention helped to maintain focus on and discussion of the issue, but, compared to land-based pollution sources, the rate of regulatory action has been appreciably slower.

This thesis analyzes vessel emissions with a focus on one industry sector – international containerized shipping. It could be argued that all MTS areas contribute to the problem and should be included for study, but just as tankers are the primary objectives of oil pollution work due to their structure and volume, container vessels, more than any other international category, have distinct mechanical, operational, and geographic characteristics that make them a greater independent risk for air pollution.

The system of containerized shipping consists of a network of individual stakeholder groups that are, independently, very strong – often described separately as industries. Each of these units is accustomed to addressing issues, such as security, infrastructure development, the environment, and safety, from an individual corporate or category (shipper, carrier, port, etc.) perspective rather than as a cooperative unit within a transportation network. This is partially due to the fact that there is no controlling, over-arching body, as in domestic situations, guiding coordination and also partially because current regulatory bodies tend to single out individual parties for directives – not treat the system as a network. Each of the MTS participants, however, is linked to other members through very powerful market and business forces. Decisions made by one category, thus, readily induce domino effects on other members, impacting subsequent choices and actions. Industry and government leaders, therefore, must acknowledge the significance of and the relationships and objectives within this integrated web when attempting to address a challenge like environmental improvement [13-15, 24].

Every group (shippers, carriers, ports, policy-makers, non-governmental organizations, etc.) plays a part in industry-wide problems, so recognizing their roles and understanding their perspectives and objectives regarding possible solutions are essential. Traditionally, negative environmental externalities are brought into check through government intervention in the form of a regulation against the entities causing the harm [25]. Although this approach has its place, this work argues that, in the realm of international shipping, designing and implementing meaningful corrective actions should also include methods that facilitate cooperation and coordination of ideas and actions from numerous industry groups, domestic and foreign government agencies, and public sector organizations [12, 26, 27].

Adding each of the groups to the policy-making process enriches the debate but including them brings about positive change only if their preferences are properly identified and taken seriously [28-33]. Presently, within the issue of vessel emissions (but also arguably across the maritime industry with regards to environmental topics), there are gaps in information, including recognition of the views and values of key participants, and a less developed understanding for how those preferences could impact the decision-making or policy-making process. This point is crucial. Different perspectives translate into different motivations and, likely, a need for a mix of different triggers to facilitate change. Specific styles of environmental policy instruments are designed to create distinct stimuli for reform. The ability to choose or develop a policy that has certain triggers or incentives for action and aligning it with a stakeholder that is responsive to those elements is pivotal to ensuring the desired result, a connection that can be studied through a closer investigation into participant goals and values [34].

In addition to establishing an awareness of how the participants within the system interact, policy makers need to also understand what the industry views as viable options for addressing particular problems and why. The marine shipping industry as a whole is recognized as an area that relies on technological improvements for solutions to its efficiency and economic challenges – from the switch from sail to steam to diesel engines that enabled vessel operators to achieve faster, more reliable service at lower operating costs to more recent examples such as the evolution of containerization [26, 35]. The entire concept and process of containerization itself began as an ambitious and controversial technological invention [13-15, 24]. This concentration on technical solutions, however, is not limited to commercial applications; in fact, the environment is also an area where maritime industry leaders are actively investigating and utilizing technologies for answers. The topic of this research, the reduction of vessel emissions, serves as an example of this. With "techno-fixing" perceived as a viable and practical option, technology then becomes an integral component of the environmental policy-making process [36].

Although technical solutions are increasingly pursued as a means for addressing negative environmental impacts, an understanding of the driving forces behind technology change is not often demonstrated by environmental policy-makers. Understanding this process and how it can affect or be affected by choices within the environmental framework allows decision makers to better comprehend the most effective ways in which to apply available technical and environmental solutions. The two arenas of technology policy and environmental policy were initially introduced to accomplish different goals, but as industries, like international shipping, begin to turn to technology to achieve environmental goals, the principles of technology change become increasingly significant to the environmental policy framework.

Within the international marine transportation system, the three areas of technology, environmental policy, and stakeholder preferences are interconnected. Acknowledging this evolution and concentrating on finding methods or approaches to improve the understanding of and the ability to formulate solutions within this integrated environment is critical.

1.2 Research Objectives

1. Identify and demonstrate the significance of the interconnections between the elements of technology change, environmental policy-making, and stakeholder preferences for the issue of reducing harmful vessel emissions within containerized shipping.

2. Determine the feasibility of incorporating various stakeholder groups into the process of policy development and implementation.

    a. Utilize recognized and proven decision-aiding tools and processes to identify various stakeholders' preferences and objectives for vessel emission reduction programs.

        i. Assess which attributes and types of programs are important to which groups.

        ii. Promote discussion among stakeholders regarding the vessel emissions issue – create a more neutralized means for incorporating judgments and values into the policy discussion.

3. Express the importance of fostering acceptance of a variety of policy solutions for reducing container vessel emissions.

1.3 Research Questions

1.3.1 General

1. Is it feasible to include a wider array/variety of stakeholder groups (shippers/carriers/engine manufacturers) in the study of the policy making process?

    a. What are some of the different values that can be realized and challenges that could be encountered from expanding policy-focused research in this way?

2. What tools or practices could be utilized to aid decision-makers in recognizing, incorporating, and understanding critical stakeholder groups' values and objectives?

    a. How could those tools or practices benefit the industry and current policy-making framework?

3. Why should the technology focus of the industry be incorporated into the study of the environmental policy-making process?

    a. What are some of the different ways in which technology policy can impact the environmental policy framework for the vessel emissions issue?

4. How could researching ways in which to utilize a variety of environmental policy mechanisms impact the current policy processes for the vessel emissions issue?

1.3.2 Preference Ranking Tool

5. What attributes of programs (or types of programs) do different stakeholder groups seem to value most and least – What is important to whom?

    a. What kinds of change do stakeholder groups seem to believe is feasible?

6. Based on the exercise, how well do Advocates, Shippers, and Policy Makers know Carrier's preferences for attributes and programs?

   a. How well do Carriers know Shipper's preferences for attributes and programs?

7. Does an understanding of a (another) group's attribute preferences translate into an understanding of (their) program preferences?

   a. How do the direct attribute ranks translate into program ranks?

   b. Do the different stakeholder groups understand how flexible the attributes are – how open groups may be to negotiating changes – are there potentially misperceptions?

1.4 Significance of Study

Researchers from various government, industry, and academic forums have worked to more accurately determine the impacts and severity of the vessel emissions problem and investigate what technologically or operationally can be done to address it. The goals of this research are to provide evidence of the added value for policy-making that can be realized through a better understanding of the interconnections between the environmental objectives that are trying to be attained and the role and impacts of stakeholder objectives and technology-driven thinking on those environmental decisions; and, to demonstrate that continuing to participate in process-driven research focused on determining effective and efficient ways to stimulate industry action, will strengthen the overall environmental policy-making process within the MTS.

Efforts to make progress on the vessel emissions issue have experienced numerous challenges as groups have attempted to facilitate changes through a complicated mix of local, state, national, and international viewpoints, impacts, and responsibilities. Creating a policy framework that is more aptly able to function within this diverse environment requires a greater focus on identifying and understanding the challenges within the current policy-making processes and on determining new ways in which to update, improve, and motivate the overall system.

The process of environmental policy-making within the maritime industry is impacted by elements of technology policy and stakeholder preferences (decision theory). Recognizing, studying, and determining ways in which to further integrate these elements is important, as doing so provides constructive information on the motivations, objectives, and incentives that drive stakeholder decisions. If these elements are not recognized and investigated, there is a greater risk that inefficient initiatives, producing weaker environmental improvements or lackluster implementation will result, as the right incentives were not created to facilitate the desired changes [34]. Additionally, if the process limits stakeholder involvement or what program options are seriously considered to address the vessel emissions issue, policy makers lose access to knowledge, resources and opportunities and increase the likelihood of other difficulties.

The structure and dynamics within this international industry for this type of trans-boundary issue make the formation of partnerships and consensus building decisive. The utilization of different types of policy approaches, such as the industry-based initiatives designed to motivate and reward movement above and beyond the conventional stipulations (that are proposed in this thesis and also supported through other research projects), as well as new abatement technologies, often necessitate a much more informed and collaborative approach to program development. Therefore, the goals of understanding stakeholder preferences, utilizing a technologically focused approach, and employing a variety of program initiatives are inextricably linked, with the success of the latter strongly dependent on the ability to achieve the former [6, 10, 19, 20, 23, 37-41].

1.5 Overview of Thesis Chapters

This first chapter provides an introduction to the proposed research, including the motivation, objectives, and driving questions. The following chapters reinforce and build on those concepts and will also detail the process and results from the preference ranking exercise utilized in this research. Chapters 2 through 4 focus on background and theory. Chapter 2 presents information on the international maritime industry, the containerized shipping segment, and the contribution of that segment to the vessel emissions issue and chapters 3 and 4 look at environmental policy and technology. Chapter 5 introduces the decision theory element and details the design and implementation of the preference ranking exercise. Chapter 6 presents the results from the preference ranking exercise, and Chapter 7 contains concluding observations and remarks.

Chapter 2

THE MARINE TRANSPORTATION SYSTEM (MTS)

2.1 Significance, Function, and Structure

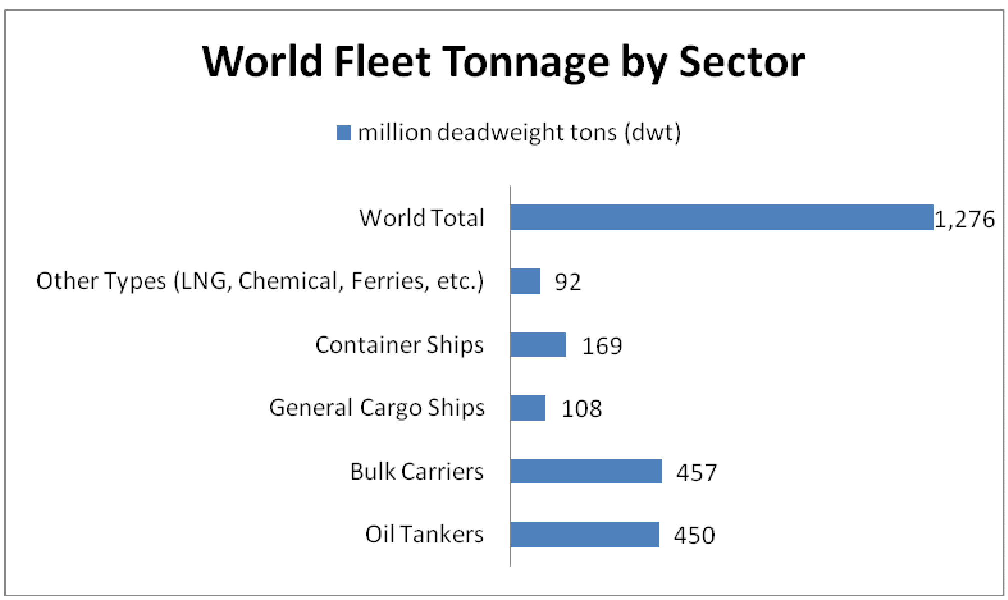
The system of global trade today is a dynamic powerhouse, commanding both enormous quantities of goods and incredible monetary value. The United States, as one of the most significant participants, serves as the leading importer and third largest exporter in world merchandise [42]. In imports, the country holds a 13.2% share with a value over twenty-one hundred billion dollars and manages an 8.0% share of all global goods exports, estimated at over twelve hundred billion dollars [42].

This flow of global commerce, at both the scale and rate of efficiency that is presently realized, would not be possible without a thriving marine transportation system (MTS), as no other mode could facilitate the movement of around 90% (by weight) of all international trade so cost-effectively [43]. Prior to the negative impacts to trade due to the financial crisis in 2008 and 2009, the shipping industry was able to accommodate double-digit growth in world trade for over twenty years with a less than ten percent increase in freight rates. And, despite the challenges in 2008 and 2009, the weight carried by sea stood at around 7.8 billion tons of loaded goods and supplied hundreds of billions of dollars in freight rates to the global economy [44].

2.1.1 The Global Fleet

In order to meet the requirements of cargo and customers, the MTS is divided into sectors that are specifically designed to accommodate the diverse types of goods traded today. Deep ocean marine transport vessels in international service today include, but are not limited to, container ships for general and high value cargo, tankers for liquids, dry bulk and breakbulk vessels for homogeneous dry products and commodities, roll-on/roll-off (Ro/Ro) vessels for vehicles and military mobilization, and passenger vessels [44].

The size of the global merchant fleet hovered at around 1.28 billion deadweight tons (dwt) in 2010, representing a 7% increase over the fleet size in 2009. As can be seen in Figure 2.1 below, oil tankers and bulk carriers currently represent the largest portion of the total tonnage at 71%. General cargo ships (break-bulk ships) make up 8.5% of the total, and the fleet of container ships in 2010 was 13.3% of the total world fleet [44].



Source: UNCTAD Review of Maritime Transport 2010

Figure 2.1 Tonnage by Sector of Global Merchant Fleet

The fact that liquid and bulk carriers represent the largest portion of the fleet may not necessarily seem surprising when considering the energy and resource demands for meeting global production and consumption requirements and where the supplies of these energy resources are located in relation to the production hubs. However, the deadweight tonnage numbers offer just one perspective of the global fleet. When other characteristics such as actual goods moved or work done (tons per km (tkm)) and vessel age are introduced, alternate views of the industry emerge [44].

The operational environment of tankers and bulkers is significantly different than that of containerized vessels. The former functions largely on an as needed basis, whereas the latter works in a much more time-sensitive, regimented system with regular and recurring sailing schedules [12, 26]. This fact translates into a tkm value for the container segment that rivals that of the tankers and bulkers, despite the notable variations in size among the fleets [44]. Additionally, when the age of the vessels in the different segments is noted, the accelerated rate of growth of the containerized fleet compared to other segments is evident.

As with many other industries, the maritime industry instituted various operational and infrastructure related adjustments during 2008 and 2009 in an attempt to try to manage the negative impacts from the financial crisis, including the recycling of older tonnage (leading to the negative percent change seen in the table below between 2009 and 2010) and modifications to routes and schedules. Leading up to 2008 though, and even now as the MTS works to recover, containerized shipping continues to lead the other maritime categories when it comes to new build and expansion. Considering that containerization is the youngest kid on the shipping block, having only become a globally mainstream category since the 1970's, this category's growth and overall place in the world merchant fleet is significant [44].

The container area commands a critical piece of the international shipping pie, making the assessment and comprehension of its operational, economic, and environmental effects of critical importance to both industry leaders and policy-makers [13-15, 45, 46].

Table 2.1 Age Distribution of Global Merchant Fleet by Vessel Type

	Years					Average Age (years)		Change
Vessel Type	**0-4**	**5-9**	**10-14**	**15-19**	**20+**	**2010**	**2009**	**2010/2009**
All Ships	28.8%	22.2%	15.8%	11.7%	21.5%	13.35%	13.97%	-0.62%
Tankers	31.8%	28.2%	16.7%	13.0%	10.2%	10.13%	10.72%	-0.59%
Bulk Carriers	25.2%	19.4%	15.7%	12.4%	27.4%	13.77%	14.27%	-0.50%
General Cargo	16.1%	9.8%	13.5%	9.8%	50.8%	21.40%	22.12%	-0.72%
Container Ships	38.9%	26.0%	17.2%	9.5%	8.4%	8.72%	9.01%	-0.29%
All Others	28.3%	14.1%	11.3%	8.4%	37.9%	17.47%	18.24%	-0.77%

Source: UNCTAD Review of Maritime Transport 2010

2.2 The Container Fleet

A snapshot of the global container fleet at the start of 2010 shows a total of 4,677 vessels (approximately 12.8 million TEU's (twenty foot equivalent units)). As was mentioned in the section above, the global container ship fleet has continued to expand in number. It also has progressively increased in average ship size. The average ship size (average TEU capacity) in 2010 was 4,942 TEU's – which is higher than the average of 4,016 TEU's in 2009, and 3,489 TEU's in 2008. Post-Panamax size vessels (greater than 110 feet wide, 1,000 feet long, or 39.5 feet deep) were considered near the top end of the ship spectrum in the early 2000's, whereas now a majority of the new incoming vessels are at or above that size [44]. The power, fuel, infrastructure, and operational requirements for ships of this size (which will be discussed in greater detail below) are significant, as are their emissions impacts.

Leading up to 2008, the container shipping industry experienced rapid growth (10.0% average annual rate over the last 20 years), fueled by continuous and aggressive growth in global merchandise trade. 2008 and 2009, however, experienced the worst global recession in over seven decades, creating an abrupt and severe decline in the volume of global merchandise trade, with international seaborne trade volumes contracting by 4.5% in 2009 – the container trade volume alone dropped by 9.0% in 2009. 2010, though, brought the beginnings of recovery, with an estimated increase in container trade of 11.5% [44]. Shifting from an environment of rapid growth to an episode of sharp decline so rapidly caused significant impacts, creating a situation of over- versus under-supply of capacity in the container segment - and all of the financial and operational challenges associated with that imbalance [44]. The road back to stability will be tenuous and challenging, but because of the push over the last decade to expand the type and variety of goods (including refrigerated and some bulk dry goods) that can be carried by container, this shipping segment will be able to take advantage of increasing volumes from stabilizing economies as they are available.

2.2.1 Container Industry Structure and Operations

The shipper category represents the companies whose goods and raw materials need to be transported. Within the container shipping industry, this stakeholder group is composed of companies representing a variety of goods, but the greatest contributors from a cargo volume perspective are predominantly large, multi-national retail corporations. As can be viewed in the following table, in 2009, the top five U.S. importers of containerized cargo were: Wal-Mart, Target, Home Depot, Dole Food Company, and Sears, and the leading exporters were: America Chung Nam (Paper/Recyclables), Koch Industries, International Paper Co., Weyerhaeuser Company (Forest/Paper Products), and Newport CH (Paper/Steel/Plastics Recyclables) [47]. These and other similar firms make their mark through the generation of products, stores, and brands that are regular fixtures within our daily lives, creating, over time, a robust, consumer driven system. It is these demands and the resources and operations necessary for providing them that continue to fuel this area and make it into a trade segment capable of producing significant impacts.

Table 2.2 The Top 20 U.S. Importers and Exporters of Containerized Cargo

Rank	Importers	Total TEU's Moved 2009	Exporters	Total TEU's Moved 2009
1	Wal-Mart Stores Inc.	684,000	America Chung Nam Inc.	259,300
2	Target Corp.	441,800	Koch Industries Inc..	120,600
3	Home Depot Inc.	278,900	International Paper Co.	120,100
4	Dole Food Co.	222,500	Weyerhaeuser Co	112,500
5	Sears Holding Corp.	216,300	Newport CH International LLC	110,900
6	Lowe's	195,000	Dow Chemical Co.	103,000
7	Costco Wholesale Corp.	166,100	Cargill Inc.	90,300
8	LG Group	149,300	Potential Industries Inc.	90,000
9	Philips Electronics North America	127,200	Denison International	86,900
10	Heineken USA Inc.	118,100	Procter & Gamble Co.	78,000
11	Chiquita Brands Int'l. Inc.	116,700	DuPont	74,300
12	Ashley Furniture Industries Inc.	90,900	JC Horizon Ltd.	72,400
13	IKEA International	90,800	ExxonMobil Chemical Co.	70,700
14	Samsung Electronics America	81,100	Cedarwood-Young (Allan Co.)	68,800
15	J.C. Penney Corp.	79,000	Shintech	66,900
16	Jarden Corp.	77,100	DeLong	65,100
17	General Electric Co.	76,700	Sims Metal Management	60,700
18	Red Bull North America Inc.	74,000	MeadWestvaco Corp.	58,100
19	Nike Inc.	72,300	Genesis Resource Enterprises	54,800
20	Whirlpool Corp.	60,900	Cellmark Group	51,300

Source: Journal of Commerce "Top 100 U.S. Importers and Exporters" - May 2010

U.S. retailers, according to the National Retail Federation (NRF), ended 2008 with sales of over $4.6 trillion dollars (U.S.), with more than 1.6 million establishments, and with over twenty-four million employees (about one in five American workers). Taken to a global perspective, the world's top 250 retailers secured total retail sales for 2009 at around $3.76 trillion dollars (down from $3.82 trillion in 2008), and conducted business in, on average, over 7 different countries (up from 5 countries in 2000) [48, 49].

The tumultuous financial environment in 2008 and 2009 strongly impacted this segment, with more than one-third of the top 250 retailers reporting declining sales. Preliminary reports for 2011, however, are showing marked improvements with rising sales numbers across the top 250 retailers due, in great part, to strong increases in consumer spending in emerging markets [50].

Logistically speaking, the sales figures for shippers translate into millions of TEU movements annually (approximately 124 million TEU's globally in 2009 and more than 27 million TEU's in annual imports and exports to the United States (up from just over 18 million TEU's in 2001 and 13 million in 1995). This kind of trade volume is an extremely powerful motivator, most especially for the next stakeholder group, the carriers - the vessel owners, operators, or charterers [45, 51, 52].

Shippers employ the carriers (either directly or through a forwarder or third party logistics provider) to facilitate the movement of their products. As was discussed earlier, a majority of containerized shipping can be categorized as a liner service – common carrier service running on established routes with published sailing dates and tariffs [26]. This is different from a tramp – common with the tanker and bulk trades - or chartered service, which addresses a particular demand or time need and as such changes regularly [26].

As with other service-based industries, the requirements for the liner trades have largely grown out of the stipulations and preferences of their customers, in this case the cargo owners – shippers. Facilitating the needs of the fast-paced, resource intensive, high volume, cost conscious, and extremely competitive retail market segment means that features such as predictability, transparency, desired routes and schedules, on-time delivery, additional supply chain services, and competitive price points hold a great deal of value. Efforts to meet these demands place tremendous pressure on the vessel operators, and these forces have transformed the container shipping market into its own fast-paced, resource intensive, high volume, cost conscious, and extremely competitive segment [12, 14, 15, 26, 45, 46, 53].

> Today the cost of transporting goods from factories to markets halfway around the world is typically one percent or less of the retail price. It costs roughly 34 cents to bring a pair of shoes that sells for $45 from a factory in Asia to a store in America. With the near elimination of transportation costs in a global economy that is open to trade, the volume of goods moving between continents has soared. Thanks to containerization, nearly everything produced for global consumption is available nearly instantaneously, nearly everywhere, at nearly the same price [13].

Maintaining a secure customer base is critical to the carriers' survival, but attaining and holding market share is a constant and difficult battle. Carrier contracts that secure cargo volumes with shippers are usually reassessed annually with U.S. based companies, meaning that vessel operators have very powerful incentives to try to find ways to distinguish their services from others and very little motivation to act in any way that could alter profitability or competitiveness [26, 46]. To get a better idea of the major players that comprise the carrier group as well as their individual trade volume capabilities, the following table displays the top twenty global containerized vessel operating companies and the total TEU capacity of their fleets in 2010.

Table 2.3 The Top 20 Containerized Vessel Operating Companies Worldwide

Ranking	Carrier	Total TEU Capacity in 2010
1	Maersk Line	1,746,639
2	MSC	1,507,843
3	CMA-CGM Group	944,690
4	Evergreen Line	592,732
5	APL	524,710
6	COSCON	495,936
7	Hapag Lloyd Group	470,171
8	CSCL (China Shipping)	457,126
9	Hanjin	400,033
10	NYK	359,608
11	MOL	348,353
12	K Line	325,280
13	Yang Ming	317,304
14	OOCL	290,350
15	Hamburg Sud	283,897
16	HMM	259,941
17	ZIM	215,726
18	CSAV	195,884
19	UASC	176,578
20	PIL	173,989

Source: UNCTAD Review of Maritime Transport 2010

Sea ports serve as the critical trans-shipment hubs. Maintaining a vital, but very challenging position in the flow of trade, ports strive to find and sustain a balance between achieving strong, positive economic gains (solid cargo volumes, revenues, and stable job growth) while limiting their negative environmental and social impacts [12, 26, 45, 46, 51, 54]. For facilities with a dedicated containerized trade focus, this process has become increasingly difficult. Just as carriers work diligently to try to adapt to meet the requirements of their very demanding clients - the shippers, sea ports also have come under a great deal of pressure to make the critical structural and operational adjustments necessary to satisfy their critical customers – the carriers. The robust expansion and development of global markets and trade has compelled these ports to adapt quickly in order to keep up with the increasing flux of boxes entering and leaving their terminals, all while simultaneously trying to manage their negative impacts and preserve an amenable relationship with any surrounding communities [7, 22, 38, 45, 46, 51, 54, 55].

Traffic, globally, declined by around 9.7% to 465.7 million TEU's in 2009 as a consequence of the financial issues experienced worldwide (though this is up from 387.6 million TEU's in 2005 and 299.3 million in 2003). The top twenty container ports manage most of these boxes (220.9 million TEU's in 2009) [44, 55]. Domestically, most of the container trade is managed by a handful of locations, with the ten largest U.S. container ports handling over eighty percent of the total U.S. container trades [52]. The Southern California complexes of Los Angeles and Long Beach manage throughputs of over 6 and 5 million TEU's respectively. However, as can be seen in the table below, with only two ports (Los Angeles and Long Beach) in the global top 20 and foreign ports such as Singapore and Shanghai independently managing over 25 million TEU's annually, U.S. ports have experienced increasing demands to devote more time, money, and energy towards expanding their containerized capabilities [12, 14, 15, 26, 45, 46, 51, 53, 54]. The above-mentioned trend towards larger vessels serves to add yet another layer of complication, as the resource and operational requirements for servicing these larger vessels (channel depth, berth size, on-dock equipment, container storage, longshoremen, and transshipment facilities, etc.) are greater [12, 14, 15, 26, 45, 51-54].

Table 2.4 The Top 20 Container Shipping Sea Ports Worldwide

Ranking	Port	Millions of TEU's handled in 2010
1	Singapore	25.8
2	Shanghai	25.0
3	Hong Kong	20.9
4	Shenzhen	18.2
5	Busan	11.9
6	Guangzhou	11.19
7	Dubai	11.12
8	Ningbo	10.5
9	Quingdao	10.2
10	Rotterdam	9.7
11	Tianjin	8.7
12	Kaohsiung	8.5
13	Port Klang	7.3
14	Antwerp	7.3
15	Hamburg	7.0
16	Los Angeles	6.7
17	Tanjung Pelepas	6.0
18	Long Beach	5.0
19	Xiamen	4.68
20	Laem Chabang	4.62

Source: UNCTAD Review of Maritime Transport 2010

The containerized shipping segment has reached the point where any development creates significant impacts, both positive and negative [13-15]. The process of determining the nature and extent of those effects, debating their merits, and developing ways in which to handle them creates increasing activity from another layer of industry participants - the governmental agencies or policy-makers, trade and business groups, and non-governmental organizations. Although certain players, such as the IMO (International Maritime Organization), MARAD (Maritime Administration – U.S. DOT), the FMC (Federal Maritime Commission), the EPA (Environmental Protection Agency), the WSC (World Shipping Council), AAPA (American Association of Port Authorities), the International Chamber of Shipping (ICS), and the International Shipping Federation (ISF), etc., have been directly involved – both domestically and internationally - in the inner-workings of the MTS for a long time, these organizations have traditionally played a largely non-intrusive role [12, 26, 43].

Today, with an expanding number of communities, businesses, and individuals being affected by this area of trade, many new groups and viewpoints have come onto the scene, encompassing extremely diverse levels of knowledge and experience and representing an even wider array of interests. For the issue of marine vessel emissions, for example, Bluewater Network, Greenpeace International, Friends of the Earth International (FOEI), the Coalition for Clean Air (CCA), and NRDC (Natural Resources Defense Council) are some of the stakeholders that have become increasingly involved in monitoring international maritime activities [23, 56, 57]. No longer known as a collection of industry spectators, this division of participants has grown into an extremely attentive, assertive, and interactive collection of viewpoints that is much more focused on finding ways in which to influence the decision-making dynamic.

As is evident from the descriptions of each of the above stakeholders, it is the dynamics of these relationships - the constraints and incentives between the major stakeholders and influential sub-groups - that create both the tremendous successes and the pervasive issues that make the container industry what it is today. Therefore, to begin to change these patterns and alter the course and attitudes of those involved in containerization from this point on, these driving forces, these limitations and inducements, must be better acknowledged, studied, and discussed. One of the goals of this research is to discover various ways in which these factors can be recognized and influenced. Learning what stimulates action, what improves acceptance, and what fosters a broader perspective would help to facilitate the advancement of any significant social, environmental, or economic goals within the container industry. However, before this work can embark on a deeper investigation of participant objectives, a better understanding of the particular problem of interest – the vessel emissions issue - and the container industry's contribution to it must be established.

2.3 Why Container Ships Are an Air Quality Problem

Recognition of the harm to human health and the environment from emissions began taking shape in the 1950's. Historically, scientists and individuals within the marine transport system believed that vessels were not a critical air quality problem because of the high level of efficiency in the engines. However, research aimed specifically at better understanding the impacts of vessels with regards to air emissions, which began in the late 1980's and has continued on to the present, disproves those early assumptions [6, 10, 19, 23, 58-64].

2.3.1 The Pollutants

Ocean-going vessels have been found to be responsible for the production of between 1.2-1.6 million metric tons of particulate matter (specifically PM_{10}, which has a diameter of 10 micrometers or less), between 4.7-6.5 million metric tons of sulfur oxides, and between 5-6.9 million metric tons of nitrogen oxides on an annual basis [65, 66]. For the purposes of this research, these three emission categories – Nitrogen Oxides, Sulfur Oxides, and Particulate Matter – will be the primary focus.

2.3.1.1 Nitrogen Oxides

NOx, which includes a range of compounds including: nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide, is largely a function of engine temperature [67]. In order to reduce it, something must be done (operationally or mechanically) to the engine or to the exhaust gases after leaving the engine [8, 10, 20, 68-74]. The health impacts from NOx (as well as the other pollutants mentioned below) are, not surprisingly, largely respiratory-based. Irritation of lung tissue is a common consequence, resulting in a range of ailments from difficulty in breathing to respiratory infections like bronchitis and pneumonia. Frequent or long-term exposure creates the most serious damage -severe respiratory malfunction, illness, and premature death – with children, the elderly, and individuals suffering with weakened respiratory functions like asthma constituting sub-groups of people who are at acute risk for these health issues. [73-78].

Additionally, NOx generates detrimental environmental impacts not only from its presence but also from its tendency to react with other elements and chemicals, creating even greater damage. Nitrogen oxides are critical components to ozone formation (a highly reactive and harmful agent), particulates, and acid rain - each of which contributes to problems such as global warming, deterioration of stone and metal structures, biological mutations, eutrophication, and loss of biodiversity both on land and in water [57, 67, 75, 76].

2.3.1.2 Sulfur Oxides

Sulfur emissions, most notably sulfur dioxide (SO_2), are directly related to the fuel oil. Therefore, low-sulfur diesel fuels, diesel fuel alternatives, or exhaust treatment technologies must be utilized to lower the levels of this pollutant [77, 78]. The health and environmental concerns associated with sulfur dioxide are similar to those for NOx, with impacts to humans focused primarily on the respiratory system - breathing difficulties (reduced respiratory volume), respiratory illness, and aggravation of existing heart and lung diseases [57]. Notable ecosystem damage due to sulfur emissions typically stems from the combined efforts of NOx and SOx together - acid rain [79]. Acid rain has long been documented as the perpetrator of significant damage to lakes, forests, and streams, as well as manmade materials [57, 75, 79-81].

2.3.1.3 Particulate Matter

Particulate matter (PM), an unfortunate byproduct of both the type of fuel and lubricants used and the heat and pressure at which they are used, has the greatest number of faces. Its composition can range from solids to liquids or gases and may be either released directly or produced through chemical reactions in the atmosphere. Sizes too can be as varied as its structure – from larger "coarse" particles (2.5 – 100 micrometers), to "fine" particles ($PM_{2.5}$ - less than 2.5 micrometers), to even "ultrafine" particles [57, 71, 81-84].

On the environmental side, particulate matter has been highlighted for its contributions to haze and staining on buildings and other structures [75, 83-86]. On the health side, investigations show that, for the most part, the smaller the particles, the greater the danger to human health, as fine and ultrafine particulates have the ability to be inhaled and held deeply within the body. What makes PM highly detrimental though is its chemical construction. Hundreds of toxic chemicals serve as the building blocks for most particulate matter. Once these substances are inside of the body and, specifically the respiratory system, their potential to do harm (either through direct damage to tissue or with mutations that can lead to more serious issues, such as cancer) dramatically increases and can have a notable impact on life expectancy [57, 81-84]. With regards to abatement, particulates, because of how they are formed, can usually be significantly reduced by implementing any measure that reduces either NOx or SOx [57, 75, 80-84].

2.3.2 Vessel Characteristics and Operations

Container ships, over any other vessel types, are critical targets for air emission reductions due to the size and power of the vessels themselves – both individually and cumulatively (globally, the container fleet represents over 60% of the total power within the MTS), the type of fuel used, their rapidly increasing trade volume, the estimated long life (in excess of twenty years) of the ships, and the kind of service involved (liner trade with established service routes and regular and repeated call times) [2-4, 23, 38, 44, 66, 69, 75, 87-89].

2.3.2.1 The Vessels

Energy consumption for vessels is generally proportional to the cube of the speed [90]. This means that in order to double the speed the energy consumption must increase substantially. Faster speeds and more powerful engines equate to more emissions and are why container vessels serve as optimal marks for emission reductions. Vessels are considered profitable only when they are moving.

Consequently, longer on and off-loading times in port due to growing container vessel size and the just in time inventory demands of shippers must be offset by comparatively higher service speeds, making container ships some of the largest, fastest, and most powerful vessels in the commercial marine transportation system [13-15, 74, 91]. For example, a container ship with a capacity of 2800 TEUs (twenty-foot equivalent units) and a dead weight tonnage (DWT) of between 23,000 and 24,000 could have a 22,000 kW motor diesel engine and reach a cruising speed of around 22 knots. By comparison, a bulk carrier vessel with a dead weight tonnage (DWT) of over 31,000 would have a 9,000 kW motor diesel engine and reach cruising speeds between 12 and 14 knots [92].

A 2800 TEU vessel would be considered small by today's industry standards [45, 46, 93]. The Emma Maersk, a ship owned by the A.P. Moller Group (Maersk Line), was the largest container ship built when she was launched in the fall of 2006. She is 397m long, has a beam of 56m, a depth of 30m, and a draft of 15.5m for an estimated 11,000 TEU capacity (13,500-14,500 TEU's without weight restrictions) and a DWT of 156,907 tons. These dimensions qualify the Emma Maersk as a "Suezmax" size vessel – the largest ship capable of passing through the Suez Canal. The engine responsible for her propulsion, the Wartsila RTA96-C, is considered one of the largest reciprocating engines in the world with 80,080 kW of power for a cruising speed of about 25.5 knots. The engine alone is 89 feet long, 44 feet high, weighs around 2300 tons, and, when working at its most efficient setting, burns approximately 1,660 gallons of HFO (heavy fuel oil) per hour [94, 95]. Today, the Emma Maersk is not the only Suezmax sized ship, as other carriers have and will be introducing additional vessels of similar size and power [45, 46].

2.3.2.2 The Engines

Almost all commercial marine vessels are powered by diesel engines. Often classified as reciprocating or compression ignition (CI) engines, this category is known for its durability, responsiveness under different loads, and efficiency with regards to fuel consumption [39, 91, 96-98]. Most container ships use a mix of these large-bore, highly supercharged diesel engines in either the low-speed, two-stroke (60-250rpm) or medium speed, four stroke (300-900rpm) form, with the vessel's size, onboard space, and overall energy needs ultimately determining the assortment that is needed for the engine room [39, 91, 96-98]. More often than not, container ships function with one two-stroke and multiple (usually three to four) four-stroke engines. The larger, more powerful two-stroke engine is responsible for propulsion, while the four-stroke engines (often labeled auxiliary engines) are utilized for supplemental needs such as maneuvering in port and managing power for onboard systems (electricity, operational equipment, on and off-loading cargo, etc.) [1, 53, 63, 64]. This combination of engines grants the carriers the speed and efficiency needed to fulfill their operational requirements but also makes commercial marine vessels the equivalent of moving power-generating plants.

2.3.2.3 The Fuel

From an understanding of the size of most commercial marine vessels, one can deduce that it takes a large volume (hundreds of gallons per hour) of fuel to keep their engines running [39, 91, 96-101] . Fuel consumption, generally, is proportional to installed power on vessels, which means that for container vessels it is a very significant operating cost, often times the single greatest operating cost. As such, vessel operators work hard to reduce this expense without compromising other vessel characteristics. In response to this demand, engine manufacturers have, over time, found ways to alter engine designs in ways that improve cost savings with regards to fuel. This has, in most cases, meant developing engines capable of operating on cheaper, poorer quality fuels [1, 77, 78, 96, 97, 99, 102].

Diesel fuel is the fuel of choice for marine engines because it offers the greatest amount of heat energy per gallon of any petroleum fuel and is also the least expensive [39, 96, 97, 101, 102]. A majority (over 90%) of large marine vessels utilize intermediate fuel oil (IFO180 or IFO380) (sometimes referred to as Heavy Fuel Oil (HFO) or Residual Oil (RO)) in their propulsion engines and either IFO, marine distillate oil (MDO), or marine gas oil (MGO) in their auxiliary engines (four-stroke diesels) [101, 102]. The table below presents the most common types of marine diesel fuel utilized in commercial vessels today. Overall, marine residual fuel sales make up the largest portion of marine fuel sales worldwide (>80%), with the sale of distillate fuels making up the remaining ~20% [44, 101]. The trade off, however, in using this cheaper, less refined fuel is a relatively high level of contaminants. Because residual fuels are created by blending the oils and residues left over after thermal cracking has removed the lighter, more financially viable fractions, impurities like sulfur, ash, asphaltenes, nitrogen compounds and metals are often common components [101, 102].

Table 2.5 Common Categories of Commercial Marine Diesel Fuel

Title	Category	Maximum Sulfur (%)	Maximum Sulfur (ppm)	Typical Sulfur Content (%)
IFO/Bunker fuel	Residual Fuel	4.5%	45,000	2.7%
IFO/Bunker	Residual Fuel	1.5%	15,000	1.5%
Marine Diesel Oil (MDO)	Distillate	2.0%	20,000	0.6% - 2.0%
Marine Gas Oil (MGO) (DMX or DMA)	Distillate	1.0% - 1.5%	10,000 – 15,000	0.5% - 1.5%
Low Sulfur Marine Gas Oil (MGO 0.2%)	Distillate	0.2%	2,000	≤ 0.2%
Low Sulfur Marine Gas Oil (MGO 0.1%)	Distillate	0.1%	1,000	≤ 0.1%

Sources: International Organization for Standardization (ISO) – Marine Fuel Specifications (ISO 8217:2010); Evaluation of Low Sulfur Marine Fuel Availability – Pacific Rim (Starcrest Consulting – July 2005)

The combined effects of their mechanical and operational features make container vessels a critical segment to study with respect to air emissions. Global fleet expansion and increasing ship and engine size and power most strongly contributes to the total amount of emissions being released, while the type of service involved (liner trade with established service routes and regular and repeated call times) determines the locations susceptible to the greatest impacts [3, 4, 23, 37-39, 58, 62, 63, 69, 75, 87, 88, 103, 104]. Container ships, like many other industrial-based investments, are built with the expectation of a long useful life (in this case more than twenty years) [12, 26, 45]. As the fleet ages, positive environmental gains resulting from ongoing technological or efficiency improvements on new ships could be dampened by a lingering population of older vessels with less effective equipment.

2.4 Summary

This chapter provides relevant information regarding the structure, operations, and dynamics within the MTS and, more specifically, the segment of international containerized shipping. Establishing a clear understanding of each of these elements is critical, as they each elicit a direct impact on the vessel emissions issue. This work contends that, within the marine transportation industry, the areas of technology, environment, and participant values are interconnected and that the current policy framework should be re-examined to better reflect this development. The above discussion of key industry characteristics offers evidence to support this first concept, and the following chapters will begin to address the second. For, in order to ascertain why and what changes are needed, there must first be a discussion of what has and is being done.

Chapter 3

ENVIRONMENTAL POLICY

3.1 Theoretical Reasoning for Environmental Policy

> Public policy is a course of government action or inaction in response to social problems. It is expressed in goals articulated by political leaders, in formal statutes, rules, and regulations, and in the practices of administrative agencies and courts charged with implementing or overseeing programs. Policy states an intent to achieve certain goals and objectives through a conscious choice of means, usually within a specified period of time. In a constitutional democracy like the U.S., policymaking is distinctive in several respects – it must take place through constitutional processes, it requires the sanction of law, and it is binding on all members of society. Usually the process is open to public scrutiny and debate, although secrecy may be justified in matters involving national security and diplomatic relations [105].

The rationale for public policy focused on environmental topics stems partly from characteristics inherent to the good itself (the environment) and partly from shortcomings that are intrinsic to the market (the private sector) and to human behavior. In a market situation, goods can most easily be accounted for through clear signals designating who controls them and who has the ability or right to buy or use them. These two elements are often defined as excludability and rivalry [25, 106, 107].

A good is considered excludable if it is "feasible and practical to selectively allow consumers to consume the good, or from a negative perspective, if it is "feasible and practical to selectively allow consumers to avoid consumption of the bad" [106]. The rivalry aspect, on the other hand, focuses on consumption. If one person's consumption of a unit of the good takes away from the total amount of that good that would then be available for others, then the good would be considered rival. Again, the "good" in this case can be positive or negative. Almost all environmental goods are non-excludable and non-rival, meaning that they do not provide a clear and easily identified indicator within the market. This situation tends to make them very susceptible to another element that influences policy intervention – human behavior [106, 107].

Certain natural elements, such as the air we breathe for example, are perceived as common property resources. It is nearly impossible and certainly not practical or feasible to keep people from using it and the use of one person does not take away from the amount available for others to breathe [106]. In the absence of misuse or harm, this factor is extremely beneficial, as the air is a tremendously valuable resource that can be utilized at no cost to the consumer. With no price, however, individuals can also exploit the supply by emitting harmful substances in the form of pollution into the air, creating a problem that has no signal in the market for correction. The business or individual has no reason to stop the damaging action, as there is a perceived benefit to them to continue and no charge or obstacle present to entice them to stop. It is the combination of all of these factors that has led to the demand for third party, in this case government, intervention [106].

Environmental impacts unnoticed by the market or private sector are identified as externalities. William J. Baumol and Wallace E. Oates define externalities with two different conditions, only the first of which must be met in order for an externality to be identified as being present [25, 105].

If a person's utility has a non-monetary element, whose value is being chosen by someone else, without attention to the desires and welfare of the individual then an externality is present.

The decision maker, whose activity is causing an impact on another's utility, is not receiving/paying an amount for the activity, which is equal to the marginal benefit/cost of that activity on the other individual's welfare.

The market has no method on its own to account for the added risk to human health and the environment that develops from increases in air pollution. An intervention in the form of environmental regulations, therefore, is encouraged to proceed on the public's behalf. A reduction in the externality – even if at the producer's expense - is perceived as being an appropriate method available to reduce the rising social costs and damages. This kind of governmental regulatory approach also allows for large and important issues like air quality to be managed on a more meaningful scale – statewide or nationally – rather than on an individual or piecemeal basis [25, 107].

Environmental quality today then, can be described as the struggle to find balance between two different concepts - the acceptance of a certain amount of pollution or environmental damage, and the support for and introduction of methods centered on reversing or preventing those negative impacts [25].

The growth in and progression of numerous environmental and other types of externalities has, over time, worked to create a thriving public policy sector. William J. Baumol and Wallace E. Oates describe this process as the public policy supply. As externalities appropriate for government action arise, organizations and programs are developed to address these demands, but, because these initiatives are so strongly influenced by the needs and wants of many different groups of people, they are subject to change on a fairly regular basis. This feature is evident from the numerous interest groups currently present in the policy sector. It is the job of those involved in these public policy-making networks to keep the issue of importance to their particular group prominent within the public sector. Maintaining a sense of urgency and attention to how problems are defined and presented is an effective means for maintaining a high level of both action and funding for dealing with specific externalities, a process that is very challenging in the presently very competitive and crowded public sector [25, 108, 109].

3.2 The Policy-making Process and Environmental Issues

The process of policy making is often depicted as a never-ending battle – always revisiting, redefining, and reintroducing problems and programs in order to maintain their effectiveness and place on the overall agenda. A strong understanding of and appreciation for specific issues by both the general public and by politically powerful individuals and organizations is critical for keeping topics viable, as there are always other items (economy, politics, external crisis or forces) continuously fighting for a space [25, 108-111].

Different methods for maneuvering issues to a more prominent (higher priority) place on the agenda are a common topic analyzed in many policy-focused readings. Authors, such as John Kingdon, emphasize the critical role that "policy communities" ("groups that try to develop solutions for particular problems and justification for their chosen resolutions") play in this process [108]. Within these communities, individuals he describes as "policy entrepreneurs" - or those "individuals willing to invest their political resources including time, energy, reputation, and money in linking a problem to a solution and forging alliances among disparate actors in order to build a majority coalition" – are critical [108]. These risk takers work to frame their issues of interest in a way that draws and keeps attention until a "window of opportunity" – a compelling intersection of recognition for the problem, desire for action, and support for the solution - opens and sparks movement forward (policy change, new policies, etc.) [108]. This tumultuous atmosphere of numerous events, individuals, and organizations keeps all of the stages of policy-making - policy formulation, policy legitimation, policy implementation, policy evaluation, and policy change – in a constant state of movement. Policymakers, administrators, the judiciary, advocates, experts, the media, NGO's, politicians, and industry each influence this process. All of these groups interact with and compete over issues as attitudes, events, people, and political controls change around them [105, 108, 109].

The state of environmental quality overall relies on a mix of individual and group values and decisions as well as collective movement in the form of public policy. Activism or in-activism in any of these areas through a change in knowledge, perception, or focus has the ability to create notable impacts – either positive or negative – a situation that has been experienced many times with environmental issues. With regards to the environment, attitudes and preferences are an important feature, affecting the subject's place of importance in the public sphere [109, 112, 113].

Environmental problems draw out very powerful responses and feelings from people because of their potential to seriously impact so many aspects of life not only now but also in the future - from human health and the needs of wildlife and various ecosystems to economic growth, welfare, and progress. "Resolving environmental issues demands, but often resists, a balance between deeply held feelings and stark confrontations among opposing views" [114]. Creating effective and equitable solutions to environmental issues within this kind of situation is incredibly challenging. Both the problems and the networks of individuals, businesses, organizations, and agencies have become increasingly complex and interconnected. The use of different methods aimed at understanding the various stakeholders' values and preferences for environmental programs, therefore, emerges as an important means for promoting productivity and movement on various environmental issues [98, 100, 103-105].

In environmental studies literature, definitive lines are often drawn citing two distinct and opposing groups at work within this system – the Environmentalists and the Cornucopians (Prometheans) [36, 115]. The Environmentalists are defined as those who give substantial weight to the environment and include preservationists, conservationists, ecologists, and deep ecologists. The Cornucopians, on the other hand, place preeminent value on economic growth, fearing that environmental restrictions serve to threaten economic well-being for individuals and populations and that increased wealth overall will lead to better health and a cleaner environment [115, 116]. Rather than relying on natural processes or efforts to try to slow the rates of change, this group promotes technological innovation as the solution to environmental shortages and problems. In reality, the distinctions are not as black and white. There is a broad spectrum of possibilities within each of these two categories. Individuals can fall along numerous points, representing characteristics that support stronger or weaker interpretations of each area's core characteristics. The push and pull that ensues in trying to find a balance between these different value systems with regards to environmental issues, however, gives the process of environmental policy-making its own distinct personality [36, 113, 115, 116].

This research contends that mainstream thinking in society today presents more of the Cornucopian or Promethean attributes than the Environmentalist ones - that we tend to be growth-oriented and promote technological advancement as well as individual and community wealth and stability. This situation is not necessarily negative. It has served to encourage advancements that have improved health, stability, and quality of life for a large number of people. The realm of public policy finds its own way to work within the goals and boundaries of this overarching set of principles, even with environmental topics. Within the environmental policy literature, this stage or perspective has been defined as ecological modernization or technological authoritarianism [116-127]. No matter the title, the basic concepts are the same – a growing interconnectedness between environmental or ecological issues with other traditional social, political, and economic areas in an effort to maintain progression and economic growth without inflicting what is perceived as too much damage to the to the environment [105, 116-128].

The gradual intertwining of production-driven goals with a level of environmental awareness has led to a progressively stronger position for technology in the environment [34, 116, 119-126, 129-135]. The now popular concept of "techno-fixing" environmental problems serves as one prominent example that supports this changing situation [120]. With more and more sectors turning to technology to provide answers to their emissions and effluent problems without overtly hindering present and future production, these two areas are increasingly moving closer together [34, 117, 120].

3.3 The Policy or Regulatory Setting

One of the repercussions of globally strong production, trade, and economic focuses is the gradual accumulation and advancement of both national and international environmental issues. What were once considered two distinct fields – trade or business policy and environmental policy – have, through the process of continuous international development, become increasingly inter-linked [34, 120, 121, 132, 136-138]. The initial response at both the domestic and international levels to these difficulties has been very similar. Following the standard procedures developed for managing externalities, legislation and agreements have been proposed and agencies, ministries, and other organizations have been assigned to oversee their execution [128, 138-141].

The subject of vessel air emissions from international shipping serves as one illustration of this trend. For example, the advantages of containerization created significant economic and operational benefits to all of its users – faster transit times, less cargo damage, lower transportation costs, etc. – which resulted in a rapid escalation in business [13, 15]. Unfortunately, this surge also resulted in social costs. Increases in transboundary emissions created air quality damage globally [3, 4, 39, 58, 62, 63, 69, 88]. Because the negative impacts were experienced at local, state, national, regional, and international levels, agencies set out to address the topic through a mix of domestic and international programs. The International Maritime

Organization (IMO) and the U.S. Environmental Protection Agency (EPA) have both acknowledged the importance of the vessel emissions issue by introducing environmental standards to address it – IMO's MARPOL (Convention for the Prevention of Pollution from Ships) Annex VI) and EPA's Pollution from New Marine Compression-Ignition Engines. The purpose of these policies was to send a clear and meaningful signal for change to the industry, but, as will be discussed in the following sections, the reality has been a cumbersome, slow-moving, and complicated process, shaped by the forces and constraints at each of the different levels impacted – local, state, national, and international [6, 10, 12, 16, 20, 21, 107-110].

3.3.1 The International Dimension

International policies often involve cooperation among two or more nations towards a common response to issues that each of the participants is impacted by or contributes to - as with domestic topics, government agencies, industry stakeholders, inter-governmental organizations (IGO's), and international non-governmental organizations (INGO's) all play a critical role in this policy-making process. Today, when the problem of focus necessitates commitments from a large group of nations, as is the case with international maritime matters, these activities are often referred to as "policy regimes" [113, 138-141].

International regimes are defined as, "principles, norms, rules and decision-making procedures around which actor expectations converge in a given issue-area." [141]. Because no international governments exists with the authority to demand or institute policies independently on sovereign nations, regimes are cooperative agreements, which makes them very different than the traditional laws and regulations that have come to populate the domestic level. Part of their structure is devoted to formal protocols that become legally binding when ratified [128, 141].

3.3.1.1 The International Maritime Organization (IMO)

As the number of international maritime conventions increased over the late nineteenth and early twentieth centuries, demand grew for an organization that could manage and encourage these changes. The International Maritime Organization (IMO) was created to address this need. Adopted by the United Nations (UN) in 1948 and officially entering into force in 1958, the IMO has been given the responsibility for facilitating communication and cooperation among governments, promoting research, and establishing baselines and technical information for safety, efficiency, navigation, and environmental protection within the area of international maritime trade. Membership is granted to nations (currently, 169 Member States and 3 Associate Members) who have ratified the IMO Convention, with observer or consultative privileges granted to respective industry participants, inter-governmental organizations (IGO's), and non-governmental organizations (INGO's and NGO's) [142-144].

The IMO is organized into different groups, including an Assembly, a Council and five main Committees: the Maritime Safety Committee; the Marine Environment Protection Committee; the Legal Committee; the Technical Co-operation Committee and the Facilitation Committee. In addition to these groups, there are also different Sub-Committees that work to support the main Committees. Topics usually begin in the individual committees and then work their way up to the discussions held in the larger assembly or council forums. New conventions must be accepted by a majority of IMO members, usually with the more technical proposals requiring a larger number of States and fleet percentage representation for approval. Because of the tremendous diversity in the participants, reaching a consensus on accepted content and requirements can be very challenging and often results in the establishment of minimum or baseline standards [142, 143].

No international governments exist with the authority to demand or institute policies independently on sovereign nations. The International Maritime Organization, therefore, can only serve as a forum for creating agreements and does not have the authority to enforce the arrangements decided upon and ratified by the member States. This responsibility falls to the individual member States themselves. It is up to them to facilitate any changes to domestic laws, agencies, or organizations that are needed to complete the ratification process and to ensure that the obliged requirements are followed successfully. Nations, historically, are accountable only for vessels registered with their flag. Limited powers over international ships are granted while the ships are in domestic waters (what is defined as Port State Control), but in most cases vessels are expected to adhere to the IMO agreements that their flag state has adopted whether in domestic or international waters [26, 141, 143].

3.3.1.2 The Role of Flag Registries

One distinctive feature within the international maritime world is the flexibility allowed with regards to how and where vessels are registered. This element is important and warrants explanation [12, 14, 15, 26, 27, 45, 145].

Carriers maintain fleets of dozens, sometimes hundreds of different vessels to manage the delivery of billions of dollars worth of cargo and to ensure a certain amount of global coverage. Each of these individual fleets, although owned by a company located in one nation, may be composed of ships that are flagged under several different nations. This fact is important. It means that individual vessels in the same fleet can be held to varying standards even though they may be, for all intents and purposes (age, engineering, engine type, etc.) identical [12, 26, 45]. As of 2010, approximately 68% of the total global tonnage is under a foreign flag or “open” registry (foreign-controlled but nationally registered or where the “country of domicile” of ships’ controlling interests is different than that in which it is registered) [44].

For the vessel owners, it is relatively easy to re-flag a vessel under a different State, but from a regulatory standpoint, it is more difficult to require States to maintain an equal level of enforcement. This re-flagging ability, therefore, can impact environmental issues. If a vessel begins to fall out of compliance in one State, the vessel operator could choose to pursue registering with a different nation that may have lower criterion rather than incurring additional costs from equipment or changes to vessel operations that would be needed to keep the ship in compliance with the current State. There is nothing to prevent the carrier from doing this and, because Flag States receive revenues from the carriers for the registration of their vessels, a State could decide to place less emphasis on certain areas, like environmental improvement, in an effort to increase overall registry volume and profits [12, 26, 45, 145].

Over time, various organizations, agencies, and watch groups have become much more aware of the potential problems inherent in this type of system and now study its impacts more closely [45, 46]. Several ideas have been introduced to address or improve the registry system, with two approaches, in particular, proving to be fairly successful in preventing mis-use or manipulation. The first focuses on increasing visibility of the membership and operations of the major foreign flag registry countries themselves to regulatory or enforcement organizations in an effort to pressure these States to improve their ratification, implementation and enforcement performance. By identifying vessels within these registries as possible or likely ‘bad citizens’, they become targets for ports or other authorities. This tactic makes it increasingly more difficult for these ships to avoid scrutiny. Another option is to focus on the companies themselves (who own the fleets) and hold them to higher levels of accountability regarding the environmental performance of their vessels (a movement that is impacted by growing corporate environmental commitments) [12, 15, 26, 27, 45, 46, 145].

3.3.1.3 IMO’s MARPOL Annex VI

Many of the IMO conventions and agreements contain provisions with environmental impacts and considerations, but the heart of the environmental portion of the IMO’s work is the International Convention for the Prevention of Pollution From Ships (MARPOL) [143]. Adopted in 1973, modified by the Protocols of 1978 and 1997, and updated through different amendments since 1997, MARPOL is considered the international benchmark for environmental protection and pollution prevention for shipping. Over time it evolved to address a growing list of environmental issues. Each of these major subjects is divided among the six different Annexes of the convention – Annex I focuses on oil pollution, Annex II on chemical pollution (noxious liquid substances), Annex III on harmful substances in packaged form, Annex IV on sewage, Annex V on garbage, and Annex VI on air pollution. Annex VI, Regulations for the Prevention of Air Pollution from Ships, was adopted at an IMO conference in 1997. It addresses nitrogen oxide (NOx) emissions, sulfur dioxide (SOx) levels, the emissions of ozone depleting substances, shipboard incinerators, and emissions of volatile organic compounds from tankers [16, 20, 111].

In an attempt to strike a balance between the expected long length of time for adoption and entry into force and the desire to implement a meaningful baseline standard, the wording of Annex VI was designed so that the requirements applied retroactively. Specifically, it affected all engines on new ships of 400 tons or greater built on or after January 1, 2000, all engines installed on offshore drilling and production units, and all engines that have completed a "major modification" (a power increase of 10% or more or any other modification that might increase the levels of nitrogen oxides) since the January 2000 date [10].

The foresight in planning for this delayed execution proved to be very important, as MARPOL's Annex VI did not officially enter into force until May 19^{th}, 2005. Fifteen States representing 50% of world merchant gross tonnage were required for adoption. Currently, fifty-three countries have ratified Annex VI, which corresponds to approximately 81.88% of the world fleet tonnage [10, 18, 59, 60, 146]. Interesting to note, the U.S. became a signatory only fairly recently, when, on Monday, July 21, 2008, President Bush signed H.R. 802 the "Maritime Pollution Prevention Act of 2008", officially stating the United State's intent to implement and ratify this Annex [147].

The time in between adoption and entry into force served as a period of much research and intense debate, as well as technological improvements – efforts that worked to further highlight the inadequacies of the current policies and stood as powerful evidence of the need to press for stricter guidelines [3, 7, 23, 37-39, 41, 58, 63, 66, 69, 75, 88, 89, 103, 104, 148]. The agenda of the Marine Environment

Protection Committee's (MEPC) first gathering after Annex VI officially entered into force (in July 2005) responded to these criticisms by incorporating dialogue on potential alterations – stronger requirements. The sub-committee on Bulk Liquids and Gases (BLG) was given the responsibility for leading, analyzing, and compiling proposals to address a critical list of targets including: stricter standards for NOx and SOx emissions, options for implementation of various emission control technologies, the inclusion of vessels built prior to 2000, acknowledgement of fine particulates (PM) and possible standards to limit them, the addition of volatile organic compound emissions (VOC's), and the issue of alternative and low-sulfur fuels [23, 59, 60, 149-152].

Follow-up meetings of the BLG committee in 2006 incorporated an air pollution working group, the beginnings of some potential amendments, and a goal for the scheduled completion of their investigations within the following year. By April of 2007, targeted revisions to Annex VI included: a three-tier system for progressive additional NOx reductions over the next 8 to 10 years, six possible options for achieving further reductions of sulfur emissions over a similar timeline, a commitment to further investigate new economic and voluntary policy measures, draft guidelines for the development of a VOC management plan, an agreement to further study CO_2 impacts and effects, and a work plan with scheduled deadlines for achieving these objectives. The following spring (March/April 2008), the sub-committee on Bulk Liquids and Gases (BLG) finally agreed on draft amendments to revise MARPOL's Annex VI [59, 60, 146, 150, 152-154]. The details regarding the proposals for achieving further NOx and SOx emission reductions are outlined in Tables 3.1 and 3.2 below.

Table 3.1 Amended MARPOL Annex VI Guidelines for Nitrogen Oxides

Amendments for the Reduction of NOx Emissions within MARPOL Annex VI				
Tier	Date	NOx Limit, g/kWh Based on Maximum Operating Engine Speed (rpm) (n = nominal rated engine speed in r/min)		
		Slow Speed ($n < 130$)	Medium Speed ($130 \leq n < 2000$)	High Speed ($n \geq 2000$)
Tier I (1997 Protocol – Applies Globally)	New engines installed from 1 January 2000 to 1 January 2011	17.0	$45 \times n^{-0.2}$	9.8
Tier II (2008 Amendment – Applies Globally)	New engines installed from 1 January 2011	14.4	$44 \times n^{-0.23}$	7.7
Tier III (2008 Amendment – Applies in NOx ECA's)	New engines installed from 1 January 2016	3.4 (Outside of the ECA, Tier II limits apply)	$9 \times n^{-0.2}$	1.96
Pre-2000 Engines (2008 Amendment – Applies Globally)	Engines installed on ships constructed on or after 1 January 1990 but prior to 1 January 2000	NOx emission limit set at 17.0 g/kW for diesel engine with a power output of more than 5,000 kW and a displacement per cylinder at, or above, 90 liters, subject to availability of an approved engine upgrade kit.		

Source: IMO Marine Environment Protection Committee (MEPC) – Resolution MEPC.176(58) October 2008

The sulfur oxide emissions portion of the Annex utilizes a global cap on sulfur content for marine diesel oil. The 1997 Protocol set the maximum allowed sulfur limit at 4.5%, a decision that met with a tremendous amount of criticism due to the fact that the global average sulfur level for marine diesel oil hovers at around 2.6 to 2.7% [99, 101]. Pressure from outside organizations as well as many member States created a strong push to adjust this portion of the Annex to a lower designated maximum allowed sulfur limit [10, 18, 59, 60, 101, 155].

Table 3.2 Amended MARPOL Annex VI Guidelines for Sulfur Oxides

Amendments for the Reduction of SOx Emissions within MARPOL Annex VI		
Date	Sulfur Limit in Fuel (% m/m)	
	SOx ECA	Global Standard
2000	1.5% - (15,000 ppm)	4.5% - (45,000 ppm)
July 1, 2010	1.0% - (10,000 ppm)	4.5% - (45,000 ppm)
2012	1.00% - (10,000 ppm)	3.5% - (35,000 ppm)
2015	0.10% - (1,000 ppm)	3.5% - (35,000 ppm)
2020	0.10% - (1,000 ppm)	0.5% (Subject to a feasibility review completed by 2018)

Source: IMO Marine Environment Protection Committee (MEPC) – Resolution MEPC.176(58) October 2008

Another adjustment that emerged with the Annex VI modifications in 2008 was the move from Sulfur Emission Control Areas (SECA's) to Emission Control Areas (ECA's). Sulfur Emission Control Areas were included in the 1997 Protocol. Identified as particularly sensitive areas, vessels operating in a SECA had to meet more stringent controls regarding the sulfur content in fuels – 1.5% maximum for all vessels. Ships were able to meet this requirement either through the use of low sulfur diesel fuel or through the implementation of technologies that had been tested and proven to reduce sulfur emissions and had been approved by the Flag State. The transition from SECA to ECA allowed Parties to petition to have particular areas designated as places where more stringent emission measures should apply, beyond just sulfur emissions. In ECA's, lower limits can now be required for sulfur oxides, nitrogen oxides, or particulate matter - individually or in combination [146, 153, 154, 156, 157]. Therefore, there are two sets of emission and fuel quality requirements – overall global standards and ECA requirements. Currently, the Baltic Sea and the North Sea are identified ECA's. In the spring of 2010, the IMO adopted specific portions of U.S., Canadian, and French waters as an ECA (North America coastal ECA). This amendment is set to enter into force in 2012, and in the fall of 2010, a proposal for an ECA for the U.S. Caribbean was submitted. That ECA is slated to enter into force by 2014 [158].

The final areas of focus for Annex VI deal with ozone depleting substances (ODS) and onboard incinerators. The intense focus internationally on greenhouse gases directly influenced the inclusion of these subjects. Ratification of the Annex forbids the installation of any type of unit that relies on the usage of ozone depleting substances. Halons and chlorofluorocarbons (CFC's) represent two of the major examples of ODS targeted for reduction or elimination with this change. Hydro-chloroflurocarbons (HCFC), another category of ODS, are allowed until January 1, 2020, and current systems are not required to retrofit. Onboard units that rely on various ODS for use that were installed prior to the January 2000 date, therefore, can remain, but any intentional releases of ODS are banned [9, 10, 18, 59, 60, 146].

The requirements for onboard incinerators represent the last piece of Annex VI. Similar to marine engines with the NOx emission specifications, incinerators for ships built on or after January 1, 2000 must meet a set of designated criteria developed by the MEPC. Retrofit, again, is not mandated for pre-2000 vessels, but certain categories, including chemical residues, polychlorinated biphenyls (PCB's), heavy metals, halogen compounds, and polyvinyl chlorides (PVC's), are now prohibited for incineration on any vessel [10, 59, 60, 146].

The amendments to MARPOL's Annex VI outlined above were approved by the Marine Environment Protection Committee (MEPC) in its 57th session (3/31-4/4 2008). These revisions then went forward and were adopted at the MEPC meeting in October 2008 and officially entered into force on July 1, 2010. Although these amendments do represent important forward steps for the industry on the emissions issue, features, such as the flexibility in the proposed timelines and reduction levels will continue to fuel ongoing debates [59, 60, 146, 150, 152-154, 156, 157].

As the IMO does not have the regulatory enforcement teeth of a typical domestic agency, periodic inspections and surveys are used to determine compliance, and the option selected for recognition of requirements is documentation. In order to be in compliance, vessels must have two key and current certificates on board prior to entry into service. The first, the Engine International Air Pollution Prevention Certificate (EIAPPC), is usually administered once the engine proves that it meets all of the necessary emission limits on the test bed. The second, the International Air Pollution Prevention Certificate (IAPPC), is provided by the State under which the vessel is flagged after the ship's initial survey. From that point on, the vessel must maintain periodic surveys (typically every 5 years) over its useful life to keep its IAPPC in good standing. Vessels representing nations that have not yet ratified Annex VI still must obtain a statement of compliance from their Flag State if they plan to operate in areas where it has been ratified [10, 97, 146]. The SOx guidelines also require that appropriate ongoing documentation be maintained to prove compliance, meaning that vessel operators must keep diligent records in the onboard oil record book to verify the essential information regarding technology use, bunkering specifications, and/or fuel switching essentials (date/time/location) [16, 112, 113].

3.3.2 The Domestic Component

The one characteristic that continues to have a tremendous impact on the advancement of the vessel emissions topic at any level – local, domestic, or international - is the role of the Nation State. Nations have the responsibility for implementation and for enforcement of international agreements and for determining environmental standards for domestic pollution problems. For the United States, the U.S. Environmental Protection Agency (EPA) has directed the creation, maintenance, and amendments of environmental standards for the protection of human health and the environment since its inception in 1970 [105, 107, 113].

The Clean Air Act (CAA), one of the earliest and most comprehensive regulations governed by the EPA, is the heart of air quality legislation in the U.S. In an effort to make the regulation more efficient and effective, the format of the CAA diversifies the responsibilities and areas of focus between both the federal and state levels of government. Essentially, it requires that the federal government specifies the overarching air quality goals for the United States and holds the States accountable for taking the appropriate actions (within their jurisdiction) to meet and maintain those federal standards. Scientific work on the various components of emissions and their health and environmental effects led to the identification of a series of pollutants determined to be the most critical. These six criteria air pollutants are - carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter

(PM_{10} and $PM_{2.5}$), and sulfur dioxide (SO_2). The establishment of targets or air quality standards was determined by the EPA to be the appropriate method for addressing these criteria pollutants. These National Ambient Air Quality Standards (NAAQS) (shown with their target levels in Table 3.3 below) were developed and introduced with the CAA and continue to serve as the overarching air quality goals for the United States [92, 94, 100, 118].

Table 3.3 The U.S. EPA's National Ambient Air Quality Standards for the 6 Criteria Air Pollutants

	Primary Standards (Limits to Protect Public Health)		Secondary Standards (Limits to Protect Public Welfare)	
Pollutant	Level	Averaging Time	Level	Averaging Time
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour	None	
	35 ppm (40 mg/m^3)	1-hour		
Lead	0.15 µg/m^3	Rolling 3-Month Average	Same as Primary	
	1.5 µg/m^3	Quarterly Average	Same as Primary	
Nitrogen Dioxide	0.053 ppm (100 µg/m^3)	Annual (Arithmetic Mean)	Same as Primary	
	100 ppb	1-hour	None	
Particulate Matter (PM_{10})	150 µg/m^3	24-hour	Same as Primary	
Particulate Matter ($PM_{2.5}$)	15.0 µg/m^3	Annual (Arithmetic Mean)	Same as Primary	
	35 µg/m^3	24-hour	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour	Same as Primary	
	0.08 ppm (1997 std)	8-hour	Same as Primary	
	0.12 ppm	1-hour	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm (1300 µg/m^3)	3-hour
	0.14 ppm	24-hour		

[Units of measure: (ppm) parts per million by volume, (ppb) parts per billion by volume, (mg/m^3) milligrams per cubic meter of air, (µg/m^3) micrograms per cubic meter of air]
Source: U.S. Environmental Protection Agency – Air and Radiation Department (epa.gov)

Some of the other tasks assigned through the Clean Air Act to the EPA at the federal level involve limiting air quality degradation in areas that are already clean (for example national parks), supporting air pollution research, providing assistance to the states for air quality programs, determining the characteristics of most fuels, and issuing emission standards for motor vehicles, all new stationary sources, and hazardous sources, as each of these areas was perceived to be beyond the purview of the states [17, 61, 159].

The states, also critical players in the CAA, are tasked with the responsibility of developing programs for meeting and maintaining the federal air quality standards. They are required to set emission limits for existing sources to ensure that the NAAQS can be attained. In addition, it is the responsibility of the states to monitor and enforce the entire system of emission regulations within their area. This requirement is fulfilled through the establishment and implementation of a State Implementation Plan (SIP), a document which lays out specifically how a state plans to reach its federal CAA requirements [17, 61, 107, 159].

Major ports tend to be located in or near large metropolitan areas [160]. Table 3.4 below contains a list of the major U.S. container ports by volume. Out of this group, eight of the top ten container ports have been identified by the EPA as areas that are either in nonattainment for criteria air pollutants (specifically ozone and/or particulate matter) or are the location of mandatory class I federal areas for visibility. While it is true that other mobile sources, such as cars and trucks, are significant factors to the air quality problems in these areas, the impacts from vessel traffic should not be discounted [19, 67, 79, 84, 160, 161]. In fact, emissions inventory work commissioned by several of these ports (including Los Angeles, Long

Beach, New York, Houston, Seattle, and Tacoma) and/or their surrounding communities has determined that emissions from vessels are preventing or have the potential to prevent these locations from reaching their mandated SIP requirements [2, 11, 21, 22, 160, 162, 163].

Table 3.4 List of the Top 10 U.S. Container Ports by Volume and Their Area's Attainment Status for EPA Criteria Pollutants

Rank	Port	Metropolitan Area an EPA Nonattainment Area
1	Los Angeles (CA)	YES
2	Long Beach (CA)	YES
3	New York/New Jersey	YES
4	Savannah (GA)	NO
5	Norfolk Harbor (VA)	YES
6	Oakland (CA)	YES
7	Charleston (SC)	NO
8	Houston (TX)	YES
9	Seattle (WA)	YES
10	Tacoma (WA)	YES

Source: Bureau of Transportation Statistics – June 2009 & U.S. EPA Green Book – Criteria Pollutant Area Summary Report – December 17, 2010

As was outlined in the previous chapter, due to the fact that a strong majority of vessels involved in global trade are international vessels - neither the sea ports nor the states have the jurisdiction to officially regulate them directly [160, 162, 163]. The federal government is the only entity that has that authority [12, 26].

The EPA, acting on its CAA obligations, produced in 1999 a series of NOx standards for commercial marine engines based on their power or per-cylinder displacement ratings (swept volume). However, at that time, the EPA chose not to set limits for the Category 3 (C3) engines - the large slow speed engines typically used for propulsion. This omission prompted a response from a coalition of non-governmental organizations – The Earth Island Institute, the Natural Resource Defense Council (NRDC), and Bluewater Network – who filed suit against the EPA [20, 21, 107]. This judicatory action ended with a settlement agreement in 2001 wherein the EPA was mandated to set emissions standards for Category 3 engines. In January 2003, the final rule for a U.S. emission regulation for new compression-ignition Category 3 marine engines was established. It directly emulated the MARPOL Annex VI NOx reduction guidelines (Tier 1 requirements outlined in Table 3.5 below) but utilized a later start date (2004 rather than 2000). Additionally, the 2003 rule set a deadline (April 27, 2007) by which the EPA was to promulgate a new tier of emission standards for the Category 3 engines as part of its obligation under the Clean Air Act (CAA) section 213(a) [160].

As 2007 approached, the U.S. EPA began to back away from its original deadline of April 27th for the promulgation of its new tier of emission standards for Category 3 engines [161, 164, 165]. Citing "long lead times" and setbacks in negotiations for new international standards at the IMO, the EPA extended its deadline to adopt a final rule until 2009 [160]. On June 26, 2009, a Notice of Proposed Rulemaking (NPRM) for emission standards for new Category 3 marine diesel engines installed on U.S. vessels was signed under section 213 of the Clean Air Act (CAA). This included two additional Tiers of NOx standards for new Category 3 marine diesel engines (outlined in Table 3.5 below). The Tier 2 standard applies to new engines installed on vessels flagged or registered in the U.S. starting in 2011, and the Tier 3 requirements will come into effect in 2016 [166, 167]. These standards, as can be seen by comparing the information contained in Table 3.5 to that in Table 3.1, are the same as those set in MARPOL Annex VI.

Sulfur emissions were also a component of the NPRM, and, here again, the EPA chose to use the same standards proposed by the IMO (Table 3.2 above). With the U.S. designating or proposing ECA's for the coastal areas and nearby islands and/or Territories, it was necessary to modify the diesel fuel program to allow for the production and sale of 1,000 ppm sulfur fuel for Category 3 engines and to put into place requirements to prohibit the production and sale of fuel oil above the 1,000 ppm limit for use in U.S. waters – especially to vessels that do not have alternate available onboard emission reducing options/technologies. On June 29, 2010, the EPA's final rule went into effect [166, 167].

Table 3.5 U.S. EPA NOx Standards for Commercial Marine Engines

Tier	Date	NOx Limit, g/kWh Based on Maximum Operating Engine Speed (rpm) (n = nominal rated engine speed in r/min)		
		Slow Speed (n < 130)	Medium Speed (130 ≤ n < 2000)	High Speed (n ≥ 2000)
Tier 1	2004 (for engines originally manufactured on or after this date)	17.0	$45 \times n^{-0.2}$	9.8
Tier 2	2011	14.4	$44 \times n^{-0.23}$	7.7
Tier 3	2016	3.4 (Outside of an ECA, Tier II limits apply)	$9 \times n^{-0.2}$	2.0

Source: *Federal Register*, Vol. 75, No. 83, Friday, April 30, 2010

3.4 Environmental Policy Mechanisms

The previous sections outlined the present regulatory setting and processes for addressing the vessel emissions issue at both the international and domestic levels. It highlights the similarities between the two, both in approach and also in common criticisms – low (baseline) reduction levels, slow implementation, etc. Creating measurable improvements across a diverse range of environmental pollutants and sources, as both the IMO and the EPA have had to do, is challenging, and, by placing the responsibility for formulating solutions for the maritime community within a single entity – the EPA domestically and the IMO internationally – it is not alarming that this has bred an approach to environmental policy-making that is very uniform in nature. The policy-makers collectively determine a standard that must be met within a designated period of time with some kind of financial tool or sanction to create an incentive for cooperation. It is true that, at the heart, "nearly all environmental policies consist of two components – the identification of an overall goal and some means to achieve that goal" [110]. Nonetheless, decision-makers do have some choice when it comes to the different types of instruments or policies that can be used to reach objectives. The challenge comes, as this work argues, in discovering how to effectively utilize a mix of available policy tools [107, 108, 110, 113, 141, 168][27, 92, 94, 100].

Typically, there are four recognized categories of policy mechanisms for addressing environmental damages: environmental standards, economic incentives, communication programs, and covenants [34, 169].

The first type, the environmental standard, which is promulgated through direct regulation, remains the most recognizable policy tool. Typically, this option requires that governments or regulatory organizations create amendments for current activities or set pollution allowances for industries and develop a system of penalties for non-compliance. These standards can be somewhat flexible, allowing the regulated parties freedom in determining the best way in which to meet the objective, or more rigid, demanding that all entities utilize the same techniques or approaches to attain the desired result. Environmental standards can include emission reduction standards, technology standards, product standards, or bans on activities or goods [34, 107, 108, 110, 169].

One of the largest points of contention between the regulated parties and the regulators when an environmental standard is being developed is time. Industry members want a certain amount of time to adjust their business and operations to facilitate the change and regulators want to initiate the alterations as soon as possible so as to avoid additional damage. Although striking a meaningful balance between the involved parties is critical for ensuring consistent participation, this negotiation process has a tendency to lengthen the time to implementation and enforcement, thus weakening the overall impacts of the programs. This can be seen with both the EPA and IMO vessel emission reduction standards discussed in the previous sections. Because the timelines for each of these programs were so long, by the time they came online their reduction levels were considered low – more of a baseline than a standard that could achieve meaningful impacts from vessel emissions reductions [35, 94, 125].

Incentive based instruments, the second type of policy mechanism, are designed to provide a recognized benefit to the industry for facilitating a change that results in environmental gains. Pollution fees or taxes, subsidies, or tradable pollution permits represent the most common forms of incentive based tools. Due to their ability to promote an efficient allocation of resources and encourage ongoing positive movement in areas that are difficult to regulate – situations where standards have been either problematic to enforce or have been unable to achieve sufficient results - this category has cultivated a growing number of proponents over time. Specifically, incentive based instruments can lower abatement costs, create a financial incentive to go beyond present standards, build a consistent demand for continual innovation, provide lower transaction costs than direct regulation approaches, and support an overall change in mindset or approach to the processes or operations that create the pollution of interest (rather than simply applying an end-of-the-pipe fix) [34, 105, 107, 108, 110, 113, 170].

Although these kinds of mechanisms possess many advantageous features, they are not without disadvantages. The primary criticism of economic incentives is uncertainty. Each situation involving an economic incentive is unique and achieving a successful outcome depends on the decision-makers' ability to determine the right incentive – the right amount for a fee, tax, or subsidy or the best rules, rates, and number of permits for a tradable permit program. This process is extremely complicated, and, if incorrect, can actually worsen the environmental problem rather than help it if, when implemented, the involved stakeholders do not respond as intended [35, 94, 97, 125, 126]. Subsidies, for example, create a market – one that is, typically, funded by a party external to the system itself. This kind of third party intervention often distorts the normal market supply and demand functions at work. If these changes create the wrong kind of incentive, then the program could actually enable polluting companies to enter and/or remain in operation longer than is optimal, resulting in a system with too many firms and too much pollution or with a market for less optimal solutions. Research on economic incentives has determined, however, specific situations where economic incentives can be very effective. For instance, subsidies work well when the risks for investing in cleaner technology are great (too great to develop a market on its own) but utilizing it is necessary to establish change or when imitation of the technology is easy [34, 107, 110, 171].

The third category of policy mechanisms focuses on communication and includes programs predominately designed to encourage and facilitate information sharing between government and industry or government, industry, and consumer. The exchange of information helps to build effective relationships among interconnected parities and also works to motivate firms to manage their operations in a way that supports movement towards the greatest environmental benefits. Examples of communication policies include options such as reporting requirements for environmentally relevant information, product information, and green labels [34, 105, 107, 110]. Labels such as the Energy Star designations from the EPA and the USDA Organic certifications from the United States Department of Agriculture serve as examples of this type of mechanism and have become readily recognized by large numbers of consumers. Facilitating open, consistent, and productive communication among stakeholders regarding environmental problems and solutions is incredibly important due to the intrinsic interconnectedness of these types of issues. Without it, the likelihood is greater for either creating initiatives that do not truly align with stakeholder needs and values or missing opportunities to develop more effective partnerships or approaches [34, 110, 113, 116, 136, 172][35, 94, 125].

Covenants, the final category within the list of environmental policy mechanisms, are voluntary agreements between industry and regulatory agencies or non-governmental organizations (NGO's). Typically, these agreements require the industry to reduce their negative environmental impacts by a certain time and agreed upon level. Known for being flexible in their design and implementation, covenants allow interested parties to join the network as they choose and often place a significant portion of the responsibility for implementation onto the businesses or the private sector. This element can be seen as an advantage, as it often serves to reduce the substantial administrative burden typically associated with policy-making processes [34, 105, 107, 110]. As with economic incentives, the greatest concern that is cited for this type of approach is uncertainty. Because covenants are voluntary, their ability to create meaningful impacts hinges on the willingness of and ongoing commitment of stakeholders to address specific problems [34, 110, 113, 136, 172][35, 94, 125].

3.5 The Role of Corporate Environmental Commitments

Businesses or industries are often perceived as having the belief that the environment is a topic that falls under the category of decreasing profitability and competitiveness, making regulatory action critical for protection or action [25, 107]. Corporations, however, especially the incredibly competitive retail and international trade companies involved in containerized shipping, are successful if they can recognize the demands of their associates and customers and integrate those needs and wants into the products and services that they provide [173, 174]. More and more, companies are investing in research to better understand the third-party effects stemming from their operations. Growing demands from investors, consumers, and affiliates for a more holistic level of understanding (to extend the range of corporate responsibilities to include environmental and social impacts of goods and services) has created a notable impact in the business landscape [136, 172, 175, 176]. Today, in addition to financial statements and operational efficiencies, firms are increasingly using environmental programs, sustainability initiatives, and socially-minded outreach projects to differentiate themselves, effectively serving as one more area in which businesses can compete [136, 172, 175, 176][99, 102, 124].

The challenge moving forward, therefore, lies not in convincing companies of the merits of environmental awareness but in identifying, discussing, and channeling acknowledged corporate environmental beliefs and values into actions or commitments – a concept that is investigated further in the study of stakeholder preferences in Chapter 5. Almost all of the major companies involved in international container shipping have created and executed corporate environmental strategies. Through these programs, firms can develop innovative solutions or chose to participate in new initiatives to improve both their environmental and business results. The addition of this type of dialogue to the vessel air emissions issue, as well as other environmental topics, could create opportunities to increase and/or improve cooperation, collective knowledge, program options, and perhaps decrease the costs associated with implementing solutions [29, 36, 110, 113, 116, 136]. With a significant body of work already in place demonstrating the environmental and health impacts stemming from global logistics practices, it is now time to better understand how to effectively align elements – such as policy mechanisms, stakeholder values, and technological solutions – to foster consistent, continual reductions in these negative effects over time.

3.6 Shifting the Focus

Each of the different types of environmental policy mechanisms - environmental standards, economic incentives, communication programs, and covenants – have been utilized at various levels (local, regional, national, and international) within the marine environment. A classic case of an environmental standard, for example, would be the EPA's regulation for marine vessel emissions [6, 160]. Economic incentive programs, on the other hand, would include dockage incentive policies, whereby Port Authorities reimburse a certain percentage of dockage or wharfage fees to vessel operators that utilize techniques or technologies to reduce environmental impacts [38, 39, 58]. Communication programs within the maritime industry have been more limited. Initiatives such as the Green Flag program that was introduced at the Port of Los Angeles and the Port of Long Beach as well as the Blue

Skies program through the EPA (both labeling programs developed to recognize the recipient (either vessel operators for the Green Flag program or engine manufacturers for the Blue Skies program) for their environmental commitment and participation) represent communication techniques, but each has a fairly limited focus [38]. Finally, the vessel speed reduction (VSR) program at the Port of Los Angeles and Port of Long Beach (which asks ships to reduce their speed to 12 knots or less within a 20-mile radius of the two Ports) illustrates a covenant or voluntary agreement in action [38, 40][35, 94, 97, 125, 126].

Each of the above categories has advantages and limitations that make them, individually, more or less suitable for different kinds of problems, stakeholders, or approaches. Determining new ways in which to utilize particular programs for specific environmental issues, situations, or stakeholders is a skill set that policy-makers within the maritime industry need to strengthen in order to support and continue to advance improvements with environmental problems, including the vessel emissions issue [27, 35, 94, 97, 98, 125, 128].

In addition to the type or kind of mechanism used, another element that will impact the policy-making process for this issue is the dynamic between state and federal authority. For example, due to the severity of the impacts from the vessel emissions issue in the South Coast Air Basin in Southern California, state regulatory organizations (the California Air Resources Board (CARB)) have used the permission to adopt more stringent air quality standards to address specific issues that is granted to the states in the CAA to implement more stringent air quality regulations for ocean-going vessels [177]. Specifically, in 2009, CARB introduced a regulation for the use of less impactful low-sulfur diesel fuels in ocean-going vessels within 24 nautical miles ("Regulated California Waters"). As this rule went beyond the standard 3 nautical mile boundary that is recognized for control by the states, it has been challenged and debated, but, thus far, has been upheld [178, 179]. States are continuing to investigate and move forward with programs, like this, that question or test the limits of state versus federal roles and responsibilities. The debates surrounding these types of initiatives, therefore, will also impact the overall dynamic of the policy-making process for this issue.

Up to this point, the primary focus of the vessel emissions issue has been defining and understanding the impacts of the problem and on investigating different techniques that can be used to address it [3, 4, 7, 62, 63, 69, 88]. Research designed specifically to delve into a more detailed analysis of how the methods and approaches are or could be used to reduce those impacts has not been as prevalent. This work argues that this should change. Discovering new ways in which to effectively combine or align stakeholders, abatement techniques or technologies, and various policy options serves as a meaningful way in which to consistently and successfully build a robust, progressive, and meaningful policy-making system – one that is capable of producing greater reductions in harmful impacts and, as the next chapter will discuss in greater detail, also providing ongoing environmentally-focused advances.

Understanding the advantages, disadvantages, possibilities, etc. of each of the different types of environmental policy mechanisms is critically important to a process-focused approach. However, in order to recognize the opportunities that are available through each of the policy types, policy-makers must deal head on with an issue that is cited repeatedly as the biggest weakness for many of these mechanisms –

uncertainty [107, 110]. An effective way to overcome uncertainty is to identify and investigate ways in which to improve knowledge – knowledge regarding what is available and possible in terms of a solution (abatement technologies and techniques), knowledge regarding how to encourage further advances or foster acceptance of current options (technological change), and also knowledge about the participants themselves and the objectives and values that guide their decisions and views. Investigating these areas – how to incorporate technology policy elements into environmental policy programs that aim to utilize technology to achieve environmental goals and how to improve the level of current, accurate, and comprehensive information regarding the views, values, and objectives for vessel emission reduction programs from all of the involved stakeholder groups – helps to shift the focus towards strengthening, enlightening, and motivating the policy-making process. It is this process that connects all of the critical elements and will serve as an effective driver for long term change.

3.7 Summary

This chapter explains the foundations of and driving principles behind environmental policy-making and describes how that framework has been applied within the marine transportation system to address the vessel emissions issue. It also contends that facilitating continuous improvement necessitates policy-makers placing a greater priority on the process side of the vessel emissions topic – on better understanding the critical elements of the system (stakeholders, abatement technologies or techniques, and policy mechanisms) and how they are connected. The following chapters explore those areas, first by investigating why incorporating key concepts of technological change is critical to the environmental policy-making framework for this issue and second by examining how decision theories and techniques can be utilized to formulate a more informed and accurate assessment of stakeholder objectives and preferences.

Chapter 4

THE ROLE OF TECHNOLOGY

4.1 Introduction to Technology

This chapter looks explicitly at the relationship between technology policy and environmental policy. For issues like the vessel emissions problem, modifications to operations (speed, routes, timing, ship size, ports, etc.) or inputs (fuel, oils, lubricants, etc.) can be viewed as less popular or feasible choices by industry participants (as was introduced in Chapter 2 (Sections 2.2-2.3). Technical solutions, therefore, suitable for vessel installation are viable alternatives. By utilizing technologies to address environmental issues, technology becomes a critical feature of environmental work. Technology treatment, thus, should be studied as a part of the environmental policy-making process. As the following sections will demonstrate, just as the choice of policy mechanism can affect the likely environmental impacts, it also has the capacity to influence the processes of technology development (innovation) and distribution (diffusion), elements that are essential to the successful utilization of any technological solution [34, 119, 132, 168].

4.2 Foundations of Technology

There is a notable amount of literature and research that analyzes the progression and implications of ‘modern’ life. Numerous scholars have debated the underlying causes and the importance of different factors that contribute to its evolution, but almost all agree on the elements that make up its core – science and technology [180-186]. Developments within these two arenas have been the focus of intense examination for hundreds of years, and the numerous impacts created through their growth in significance worked to create an incredibly powerful, self-perpetuating, progress-based cycle of dynamic positive and negative forces. Science and technology created pervasive changes to the fabric of our daily lives and they will continue to impact our social and economic views well into the future [116, 118, 121, 127, 131, 137, 180-186].

One area where the transition to a technology and science-centered existence is especially evident is in our relationship to the environment. From very early on, advances in science and technology fostered progressive movement beyond the previously accepted boundaries determined by the natural world. The distinctions of season or time of day, which once served to guide activities, became increasingly irrelevant, and growing numbers within the population became increasingly infatuated with and eventually dependent on the offerings of new innovations. Industrialization catapulted the concepts of efficiency and productivity into the mainstream, and robust economic successes resulting from those processes facilitated further advancements [115, 116, 118, 119, 121, 123, 127, 131, 132, 137, 180-188].

As scientific and technical knowledge has grown, so too has our understanding of impacts, but this has not necessarily dramatically altered how science and technology are valued. Pollution has evolved into an accepted, albeit undesirable, result of growth and technical change. The perceived benefits derived through modern advances (progress, money, efficiency, etc.) are recognized by a majority of the population as far outweighing the identified ecological losses, thus allowing this mindset to perpetuate [115, 116, 119, 122, 123] . This mentality - nature as a commodity and humans as managers - has gone through several different iterations over the last hundred years with, arguably, the most significant alterations occurring within the last fifty or sixty years [125-127, 130-132, 134, 180, 184, 186, 187].

Technology-focused literature identifies the 1950's and early 60's as a time when there was great confidence around the concept of being able to address issues that arose from modern lifestyle choices through additional knowledge or capabilities (a phase of Technological Authoritarianism). Technology was identified as the key. It allowed society and businesses to achieve the continued progress that they had come to demand and also provided solutions to problems that may transpire along the way. Abstaining from polluting activities was superfluous from this perspective, as further investigations would eventually reveal a proper means for mitigating any potentially harmful results [115-117, 119, 120, 122, 125, 126, 132, 182-186, 189].

A decade later, however, research confirming the significant and often negative impacts of fifty or so years of "modern" choices combined with ideas from the new environmental movement (in the late 1960's through the 1970's) began to challenge many of the core principles of modernity. Some feared the ecological irreversibility of earlier as well as current technical decisions and started to increasingly identify technology as a critical problem for, rather than the solution to emerging environmental issues [16, 34, 36, 105, 111, 116]. In spite of these findings, many scholars such as Herbert Simon, Nathan Rosenberg, Vernon Ruttan, Chauncey Starr, and Richard Rudman (among others) continued to promote the possibilities of science and technology. They challenged the dissenting arguments through additional work supporting the significance of technical knowledge and technological change as a critical means for developing long-term solutions for environmental troubles. This viewpoint held and evolved into a period focused on the development and implementation of "green" or environmental technologies [24, 115, 119, 121, 125, 130, 132, 135, 172, 182, 184-187, 190].

4.3 Environmental Technologies

Environmental technologies are defined as methods or objects designed to either safeguard or re-establish environmental quality – either directly through pollution management and recycling or indirectly through the introduction of processes or products which are less environmentally harmful than previous or present options [34, 132, 172]. Generally, these technologies fall into one of six categories: pollution control, waste management, clean technology (process-integrated production technologies), recycling, clean products, and remediation or clean-up technology. Through the development of these techniques and additional research designed to address potential or actual negative impacts all along the production and consumption cycles, science and technology have created a unique niche within the realm of the environment. Advances within each of the environmental technology categories consistently receive notable political, social, and economic support, becoming known as the solutions that will be able to lead us to create a lesser impact on the natural world, while not losing the modern features to which we have become accustomed [34, 115, 119, 121, 130, 172, 180].

In many industries, including the maritime industry, the idea of "techno-fixing" or utilizing technology as a way to engineer solutions to environmental troubles is pursued, making the goal now about finding a way to strike a balance between our ability to create an impact and the environment's ability to absorb those changes [34, 119, 120, 172]. This change solidifies science and technology as a critical part of the environmental debate, while ongoing research and findings within the above six categories further entrenches these two categories as necessary features within the environmental policy framework - whether through the formation of alternatives, decision making, implementation, or evaluation [116, 119, 121, 130, 168, 180, 182].

4.4 Technology Change and the Technology Path

Understanding the driving forces behind the process of technology change and how they can affect or be affected by choices within the environmental framework allows decision makers to better comprehend the most effective ways in which to apply available technical and environmental solutions [34, 35, 119, 132, 134, 172]. This section works to identify and explain the elements of technology change through a detailed investigation into the process and characteristics of the technology path.

4.4.1 Technology Change

At its core, technology change involves a manipulation of resources, or more specifically, an improvement in the relationship between inputs and outputs – achieving more output with the same, different mix of, or less volume of inputs [24, 34, 185]. Therefore, considering the main contributors to the production function – labor, capital, resources (energy), and knowledge, technology change impels these elements to become more efficient by introducing new, more effective products or processes and causing shifts of and within the production function through their evolution [24, 35, 133, 174, 191]. It is a process that can occur through an adaptive, problem-solving progression - the search for a "successful solution to a particular problem thrown up in a particular resource context", or through findings and advances discovered during research and development aimed at a broader array of applications [24]. No matter how it transpires, formulating a better understanding of technology change is critical because it has the potential to alter not only the nature and character of work but also the social structures surrounding that work, making it a significant force for both business and society [35, 124, 174, 182, 183, 186, 192].

The process of technology change is comprised of three elements: invention, innovation, and diffusion. The interplay between these elements and the progression through them creates advancements within firms and/or industries – a technology path. Figure 4.1 below presents a graphic interpretation of this technology path [24, 34, 35, 124, 133, 188, 193, 194].

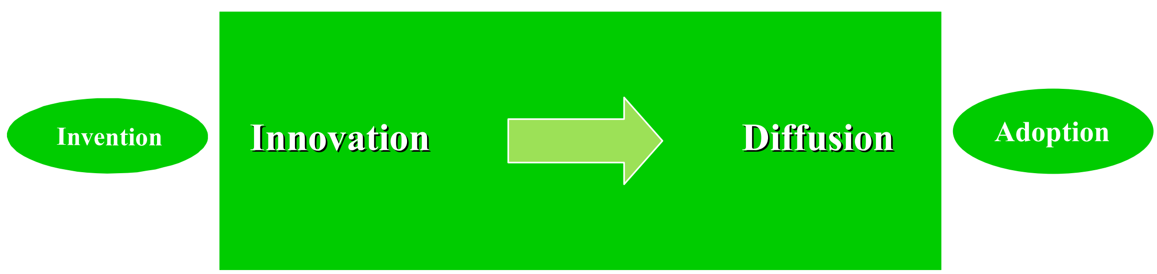


Figure 4.1 The Technology Path (Grubb and Foxon 2003)

4.4.2 Invention

An invention is most readily described as a new technical principle and can come in the form of an idea, sketch, or model [24, 35, 133, 137, 181]. Under that broad definition, the literature further separates this concept into two more specialized classifications: micro-inventions and macro-inventions. Micro-inventions are typically incremental in nature, often stemming from experiences and ideas from actual industry participants out in the field. New products or processes falling within this category occur regularly and tend to realize the greatest benefits through improved efficiency or productivity. However, because each new micro-invention serves as a stimulus for additional refinements, the gains from these developments tend to decrease over time as new ideas, sketches, or models are introduced to replace them [24, 34, 124, 185, 188, 194, 195].

Macro-inventions, on the other hand, are considered dramatic departures from the present status quo [24, 35, 137]. They are much more irregular in occurrence than micro-inventions both in number and affected sector, and the opportunities, benefits, or changes afforded by them are more radical than the results realized from incremental additions. However, the impacts from macro-inventions can be more limited then micro-inventions due to the level of specialization in the industries or areas in which they may arise. Because macro-inventions result largely from focused R&D work, industries with a strong and deliberate concentration on research and development are more likely to realize greater numbers of and profits from these types of inventions [34, 181, 184, 185, 187, 192, 194].

4.4.3 Innovation

Innovation follows invention and represents the process of adapting and introducing an invention into the market. Often defined as prototype development, it is identified by the first economic transaction with the new product, process, element, tool, etc. [24, 124, 181, 194]. Again, the literature separates this step into two different models - incremental or radical - depending on the nature of the parent invention. Incremental changes are the most common and typically involve improvements that are realized through a streamlining of currently available processes or products based on new information and findings from users. Innovations within this category can produce significant economic and productivity benefits to a given field or company (positive shift along the production function), but, as was described above, they often realize diminishing returns over time as improved innovations are periodically brought online [34, 133, 137, 185, 186, 188, 194].

Radical innovations, or innovations that involve new knowledge, resources, and significant technical advancements, although less common, have produced extremely important advances throughout history, creating waves of change across many fields or industries – often completely altering the way that things are done. These precedent-setting innovations tend to be the offspring of intensive exploratory R&D work. This detail makes them more sporadic in occurrence. However, while their impacts often ripple across many different sectors and have the power to trigger an actual shift of, rather than along, the production function, their economic benefits, historically, tend to be smaller and more localized than their incremental counterparts [24, 34, 35, 137, 181, 185, 187, 188, 194].

Because innovation is marked by a firm or field's investment in a particular invention, it is not surprising to discover that market factors have a strong influence on the process [24, 35, 190, 194]. Often considered expensive and highly complicated, innovation of either the incremental or radical variety is usually fiercely protected and highly competitive, contributing to the creative destruction dynamic that Joseph Schumpeter recognized within the business and economic landscape [188]. As companies or industries continuously strive to develop new and inventive ways to distinguish themselves through innovation, some will advance through successful experiences and others will fail. Both of these outcomes are important and necessary to the innovation process, as each serves, in its own way, to perpetuate technology change [24, 34, 35, 137, 181, 185, 187, 188, 194, 196].

4.4.4 Diffusion

Diffusion, the next stage of technology change, relates to how new technologies are adopted. This step is critical because it directly determines the economic and social impacts of a given innovation. As with invention and innovation, diffusion also can be separated into two distinct models - epidemic or rational choice [24, 34, 35, 137, 181, 185, 187, 188, 194].

Epidemic diffusion, in line with macro-inventions and radical innovation, involves the adoption of new technologies or technological processes that represent a dramatic shift from or to the current state. Although it is not immune to economic considerations, this type of diffusion is most strongly guided by changes in knowledge or new findings than by other factors, typically resulting from concentrated research and design work within specified fields or firms. Technologies following this pathway are accepted by users because they represent new findings or knowledge, which results in the generation of a new need or preference that would not have been possible before [24, 34, 35, 137, 181, 185, 187, 188, 194].

Rational choice diffusion follows the incremental approach, whereby new technologies or technological processes are adopted as the result of aggregate economic decisions by individual adopters. The appointed user makes a set of calculated, gradual judgments regarding the technology. In order for the technology to be adopted, it must surpass specified thresholds that the field/firm has set. The threshold can be determined by several factors but is usually based most strongly on economic elements (cost of technology, savings over old technology, increased profit from new technology, etc.) [24, 34, 35, 137, 181, 185, 187, 188, 194].

The prevalence of this type of technological diffusion explains why older, less efficient technologies continue to remain in the system even after new innovations have been introduced [24, 185, 194]. By following the accepted principles of rational choice, if the high "switching costs" associated with a new technology are beyond some firms' approved critical levels, then it is irrational (in their minds) to adopt the new product or process immediately. If, however, the environment or influences surrounding the given innovation change in a manner that allows various thresholds to be surpassed, then it is likely that more organizations will consider adoption [24, 34, 35, 124, 133, 137, 181, 185, 187, 188, 194].

A practice often described as wavelike, both epidemic and rational choice models of diffusion usually begin with a limited number of pioneers, followed by an increasing pool of competitors as the market adapts to the new addition [24, 133, 185, 188, 191, 194]. Eventually, a "dominant design" emerges and the group of competing firms contracts as the profitability potential wanes from saturation within the market and a settling of supply and demand functions. It is this lull period following the establishment of a dominant design where new opportunities tend to emerge. With smaller threats present from potential competitors and higher gains available for those willing to take the risk, this situation serves as an optimal time for the introduction of new innovations [24, 34, 35, 137, 181, 185, 187, 188, 191, 194].

Diffusion is driven by acceptance and a desire for ownership [24, 35, 184, 185, 194]. It can occur at dramatically different rates (depending on the personality of the firm or field) and often does involve some initial risk for the first adopters. The diversity that is present within any given pool of potential users (different goals, knowledge, competitive or regulatory pressures, time preferences, and risk aversion) makes the process of diffusion very dynamic. Additionally, there are a variety of external elements that can impact the decision to adopt that also must be considered including: the item or process itself (price, performance, costs, installation and operation), the level of competition, the social or regulatory pressures, overall preferences and values, the perception and attitudes towards innovation or new technologies, availability, targeted marketing, and the difficulties inherent in gathering and analyzing additional information [24, 34, 35, 137, 181, 185, 187, 188, 194].

4.5 How the Stages Fit Together

As the previous sections demonstrate, the process of technology change is one of constant movement where findings, activities, and feedback at each stage directly impact the expectations and possibilities available at other points along the path. Invention lays the foundation and begins to define the boundaries, characteristics, and costs of the new item or process that is then refined and streamlined through the course of innovation. Diffusion, finally, determines the life of the innovation in the marketplace. It primes our ability to both accept and demand new objects, ideas, and methods of work, and creates opportunities for additional inventions and innovations by widening the total population of users [24, 34, 35, 124, 133, 137, 181, 185, 187, 188, 194].

4.5.1 Knowledge

Running in the background between each of these three elements is knowledge. Knowledge and learning enters the system through many different channels and has the ability to dramatically impact both the trajectory and the pace of overall development [24, 35, 173]. Acknowledging and investigating the impacts of knowledge and learning is critical for comprehending the process of technology development because it directly relates to how different organizations interact with the technology path. Not every field or firm learns or thinks about technology in the same way. Characteristics such as risk acceptance, pace (fast or slow), size, the type of product or process being provided, and competition can all affect how an entity learns or thinks about technology [24, 35, 173, 174, 196]. Variations in any of these features can influence an entity's openness to technology change, its focus along the path (the importance of development over absorption), the perceived benefits to it from ongoing support of R&D, or the methods best capable of motivating it to pursue or adopt new developments [35, 119, 129, 173, 182, 184-187, 190, 191, 196-199].

Typically, it is found that - the faster the pace, the more technical the product or process, the more competitive the field, the more diverse the company, and the greater the willingness to take risks, the stronger the focus on encouraging in-house research and development, regardless of overall company size [35, 173, 174, 196, 197]. Firms functioning within this type of environment have realized tremendous benefits from this approach - from increased profitability and efficiency to a compelling capacity to creatively incorporate outside knowledge - positive results which motivate them to continue to stay ahead of the curve. Taking on the role of a first-mover, though, necessitates that these types of organizations maintain a heavy focus on the areas of invention and innovation. R&D that is concentrated at these two stages tends to provide a certain level of protection and control that, due to the pressures to maintain strict confidentiality and to stand apart from other similar firms, organizations find extremely valuable [24, 35, 172, 173, 185, 187, 191, 194, 197-199].

Conversely, firms that are more risk averse or have a less technical focus tend to concentrate more of their attention on diffusion and rely on research from other organizations to inform their decisions or create opportunities for new directions [35, 173, 174, 196, 197]. Economic considerations are the most critical factors for technology acceptance here, making the rational choice variety of diffusion the common pathway. These companies will adopt innovations once they have proven their worth. Size, in this case, generally determines how quickly a new item or function is able to be implemented. Smaller firms have fewer internal organizational hurdles, which typically allows for a faster rate of adoption [24, 35, 172, 173, 185, 187, 191, 194, 197-199].

4.6 The Maritime Industry and Technology Change

Figure 4.2 below expands on the technology path graphic presented above (Figure 4.1) to include stakeholder groups as well as the typical relationship between those parties and the process of technology change. As Chapter 2 described, the participants within the international container shipping industry represent a diverse array of firms and organizations – each with its own unique mission or focus, attitude towards environmental topics, and business methodology.

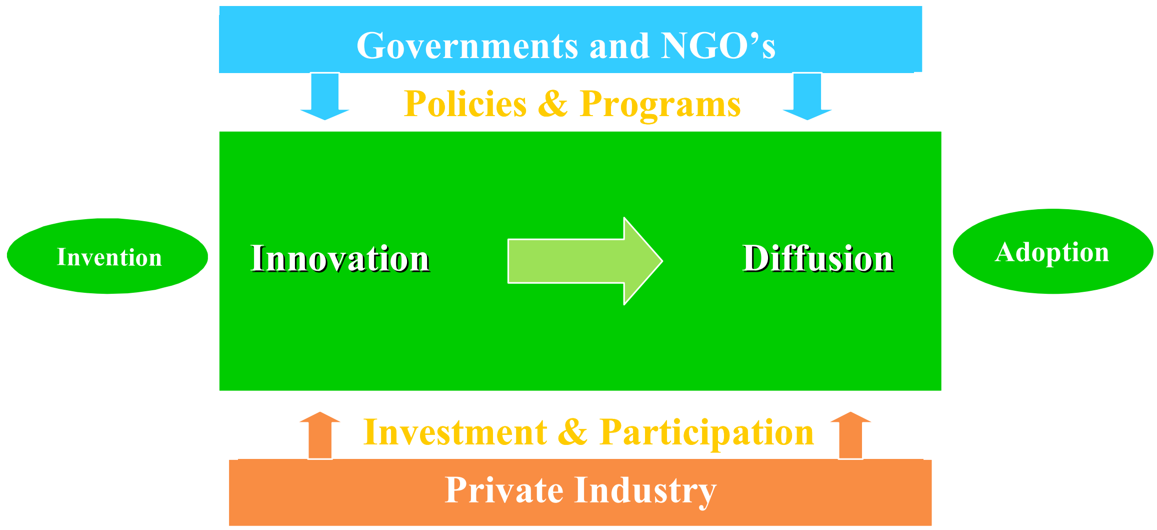


Figure 4.2 Finding Interconnections between Technology, Stakeholders, and Policy Mechanisms (Adapted from Grubb and Foxon 2003)

4.6.1 Policy-Makers and Non-governmental Organizations

On one side of the path are the policy-makers and the non-governmental organizations (NGO's). These groups interface with the process of technology change through policies or programs aimed at identifying, publicizing, studying, encouraging, preventing, or enforcing industry actions [34, 105, 107, 108, 110, 116, 141]. While policy-makers are the groups granted with the responsibility and legal authority (jurisdiction) to develop and implement, in this case, environmental programs, characteristics such as size, organizational structure, range of issues, and political influences often encumber the speed and manner in which problems are approached and addressed [36, 111, 113, 119, 130, 132, 139, 200].

Non-governmental organizations, on the other hand, are much smaller and more nimble. Although they do not have the ability to directly enact legislation, these groups can influence the rate and course of the overall policy path for a given issue. NGO's possess diverse, active, aggressive, and well-informed staffs that are well adept at highlighting areas of concern, building and mobilizing support, and assertively pressing for action. By limiting or encouraging certain industry actions or inactions, these stakeholders can influence or adjust the technology pathway [23, 34, 36, 56, 105, 107-111, 113, 116, 119, 128, 132, 134, 141, 201].

4.6.2 Industry Participants

On the opposite side are the industry participants – the vessel operators (carriers) and the shippers. These companies interact with the technology path through investment and participation. As problems emerge, policies are instituted, or new innovations are introduced, these two participant groups adapt and react through various technical and operational alterations and advances within the system [12-15, 26, 53, 202, 203]. Observing and understanding key influences to the technology change process, such as risk acceptance, pace (fast or slow), size, the type of product or process being provided, and competition, for both carriers and shippers provides valuable insight into how they relate to the technology path and, thus, how best to motivate productive advances for technical problems such as the vessel emissions issue [24, 34, 35, 119, 132, 134, 174, 184, 186, 187, 194, 197].

4.6.2.1 Vessel Operators

Vessel operators, or carriers, function in a highly competitive environment. Their main focus is moving cargo from place to place as fast, at the lowest cost and as efficiently as possible. In containerized cargo, the freight rate, the fee charged for moving cargo from point A to point B, is often times based on the value of cargo in the box. However, no matter what the value of the cargo, the rate is kept at a fee per box that just covers the fixed and variable costs of the journey with a small profit [13-15, 26, 53, 90, 204].

Because of the instability inherent in this system, carriers tend to focus on providing a service and count on other organizations to absorb the increased risks and expenses involved in developing innovations for items such as engines or vessel design and development. Carriers, therefore, rely most heavily on diffusion of available technologies from other areas (engine manufacturers, ship yards, etc.), rather than on intensive internal R&D (innovations), specifically, rational choice diffusion [13-15, 26, 53, 90, 204].

As the pressure to address vessel emissions increased, carriers evaluated and accepted various methods for reducing their negative air quality impacts [13-15, 26, 53, 205]. From the beginning, two pathways were available to the carriers to achieve these desired environmental improvements – operational methods whereby the vessel would be required to alter its procedures in some way (for example, use different fuels or travel at specified speeds in identified locations) or technology-based methods [39, 71, 90, 91, 97, 102, 103, 148, 206, 207]. New emission-reducing technologies, however, are not inexpensive to purchase, install, or operate (details regarding emission reducing technologies can be found in Appendix C below) [39, 71, 89, 91, 97, 104, 148, 206]. Persuading carrier's to adopt these products, therefore, has met with some hesitation due to the fact that many times they appear to have a cost without a great enough benefit or return on investment [34, 35, 39, 71, 89, 91, 97, 104, 148, 194, 206].

Understanding how the vessel operators interact with the technology path provides important information that can be useful for formulating new options that work with, rather than against, this interaction [34, 35, 89, 185]. Programs aimed at lowering or disabling economic and operational thresholds offer potential and could be accomplished through a variety of policy or program options. Additionally, identifying and manipulating known triggers for vessel operators would provide policy-makers with an opportunity to not only impact new vessels, but also the in-service vessels available for retrofit [35, 39, 66, 68, 132, 148, 172, 185, 194, 206, 208-210].

4.6.2.2 Shippers

Shippers are critical members to the MTS, as it is the movement of their goods which drives the business, but, as a stakeholder group, they are not always included nor do they consistently pursue active participation in the array of key policy issues affecting the industry. Their focus largely remains limited to finding a carrier who can provide them with the fastest transit and adequate customer service at a good rate. Beyond the regular freight rate negotiations, therefore, shippers tend to have restricted interactions with other maritime stakeholders or activities [12, 14, 26, 202-204, 207].

This situation, however, could be encouraged to change. A list of major shippers within the international container world includes several well-known, multi-national corporations –Wal-Mart Stores Inc., Target Corporation, Home Depot Inc., Sears Holding Corporation, Dole Food Company, DuPont, etc. (see Appendix B for a complete list of the top 50 U.S. Importers) Each of these firms is considered a leader or trendsetter within their area of focus [202, 203, 207]. As such, any alterations to their operations, mission, or business practices create notable shifts and reactions across numerous sectors. One such factor, which was discussed in detail in Chapter 3, that has gained support and become an important topic within a significant number of these organizations is the environment [34, 136, 172, 176, 183, 204, 205, 211, 212].

As with the carriers, the setting in which the shippers operate is also highly competitive. However, unlike the more conservatively-minded vessel operators, shippers function within an environment much more conducive to invention and innovation – fast paced, diverse operations, highly protective, technically-minded products and processes, and a willingness to take risks. In looking for new ways to stay ahead of the curve or differentiate themselves from other similar organizations, many of these companies are exploring and utilizing the environment as a means to integrate growing consumer and business demands for environmental responsibility into their business [34, 136, 172, 176, 183, 204].

Terms such as sustainability, energy efficiency, and environmental footprint are now recognizable terms within business rhetoric [16, 36, 112, 113, 116, 136, 176, 213-216]. In an effort to repair, augment, or distinguish the image associated with a particular brand, a growing population of shippers has begun to assess the type and intensity of environmental impacts from their operations, internally or externally through hired consultants [34, 113, 116, 136, 176, 205, 211, 212]. As this type of research continues to expand, firms are becoming more informed about the nature and degree of their impacts – work which could be encouraged to focus more on a specific area – logistics.

The expansion of global markets combined with reasonable transportation costs has allowed companies to develop critical segments such as production, manufacturing, and product development in locations all over the world [12-15, 26]. Logistics, or supply chain management, therefore, has grown to represent a significant portion of a shipper's overall operations. Finding ways to align the logistics element and the environmental element serves as a ripe opportunity for environmental policy research. Projects or programs aimed at merging these segments would appeal to the innovative nature of shippers, as it would be trendsetting with great potential for positive branding, while any contribution of funds or secured market share would simultaneously serve as powerful and effective "threshold reducers" from the carrier perspective [34, 35, 37, 66, 119, 132, 134, 172, 174, 184, 185, 198].

4.7 Technology and Environmental Policy

The previous chapter on environmental policy (Chapter 3) identified four different types of environmental policy mechanisms: environmental standards, economic incentives, communication programs, and covenants. Each of these is designed to create environmental improvements through different means and also has the ability to influence the various stages of the technology path [24, 34, 132, 169, 172, 185].

4.7.1 Environmental Standards

Environmental standards, promulgated through direct regulations, are the most recognizable policy tool. They typically involve government-determined standards for activities or pollution allowances within or across industries with a system of penalties for non-compliance. Emission reduction standards, technology standards, product standards, or bans on activities or goods all fall under the environmental standard category [25, 34, 105, 107, 108, 110, 128, 169, 170].

As each of these options is geared at defining and maintaining compliance, they have the strongest impact on diffusion [34, 119]. When policy-makers establish standards, they usually do so with certain products or processes in mind. Thus, once they are in place, they serve to stimulate diffusion in line with those options. Because the standards act as thresholds, innovation tends to be limited to incremental steps. Organizations have little motivation to strive for more sweeping change as regulations historically have been enforced only after techniques able to achieve the requirements have been created [107, 110, 111, 113, 128, 132, 140, 169, 170, 186, 194].

Environmental standards, therefore, operate as a limit or starting point for additional action. However, because they seem to best support only one segment of technological change – diffusion – and are focused on only certain industry participants, there is value in moving beyond standards to explore policy alternatives that can influence other areas – invention and innovation – and groups [35, 105, 110, 113, 119, 128, 172, 184].

4.7.2 Economic Incentives

Designed as a means to stimulate movement and environmental gains beyond environmental standards by creating ways to benefit firms for supplemental changes or reductions, this technique can motivate invention, innovation, or diffusion within a given sector. Rather than establish an industry requirement, economic incentives introduce an incentive or signal but place the burden of determining the method to achieve that endpoint onto the firms [25, 34, 39, 107, 110, 111, 113, 116, 132, 135, 169, 217]. The flexibility inherent in this action allows the organizations to test their knowledge and experience, developing new and innovative ways to attain the desired goal. Discoveries found through these activities can enact greater technical impacts and environmental results. As companies have a vested interest in establishing cost and operationally efficient solutions, the proposals tend to move beyond the traditional end-of-pipe answers to more process-integrated possibilities [24, 35, 37, 66, 68, 89, 119, 129, 132, 135, 148, 168, 172, 185, 186, 206, 209].

Because of the vast geographic area, the transitive nature of the vessels themselves (moving in and out of different routes based on seasonal and business needs), and the inherent jurisdictional and political quagmire involved, creating either a tradable permit scheme or a pollution tax or fee for the international MTS may not be feasible or meaningful beyond specified regional areas [3, 16, 25, 34, 39, 97, 106, 107, 110, 138, 141, 169, 171, 217, 218]. Rebates, on the other hand, have been researched and effectively employed in locations within Europe, the Netherlands, and the United States as viable options for inducing additional reductions from participants [7, 11, 20, 38-40, 66, 70, 75, 219-225].

By offering discounts or refunds off of regular expenses (such as dockage or wharfage fees) to carriers who utilize emission abating technologies or techniques beyond what is currently required by law, this policy option provides recognizable and valuable incentives that appeal directly to this group's rational choice mentality while also creating supplemental environmental gains. Identifying other locations or instances where discounts could realistically be applied would be an opportunity that offers great technological and environmental potential. Diffusion would certainly be impacted through this type of measure. Additionally, formulating rebate initiatives in support of prototype development and testing would also generate significant advantages for innovation [24, 34, 35, 128, 132, 135, 169, 172, 185, 186, 194, 226]. Developing an appropriate value or range would be essential for obtaining the desired program results with any economic incentive, but because the kinds of costs involved – equipment, operational inputs, labor (installation and maintenance), etc. – would be fairly straightforward and readily determinable. This would not be enough of a challenge to warrant not using these types of programs.

4.7.3 Subsidies

As was stated in Section 3.4 above, subsidies for environmental programs generally involve a provision of funding to an industry or firm for investment into or production of cleaner technologies or processes. In this way, it works to promote both invention and innovation if the focus is on development or diffusion if the technology is selected and a market is created for a particular environmental item or procedure [24, 34, 110, 128, 172, 185, 194].

In an environment where the risks for investing in cleaner technology are great but utilizing it is necessary to establish change, subsidies have the power to serve as a necessary stimulus. Also, if the development time for a particular technology is long, then subsidies may also be appropriate, as fewer companies would be likely to sign on to such a long term commitment [25, 34, 106, 107, 110, 132, 169, 171]. One area within the international container shipping industry where some sort of subsidy aimed at supporting and advancing R&D work may be appropriate is with the engine manufacturers. Engine manufacturing for commercial marine vessels is high-paced, incredibly competitive, very technical, and intensely focused on establishing proprietary discoveries, a combination of expensive and risky attributes that has kept the number of companies involved very small [26, 39, 45, 68, 71, 74, 91, 97, 148, 208-210, 227].

Engine manufacturers have researched and produced (on a small scale) more environmentally friendly options for marine vessels. Findings related to new kinds of software, equipment, and materials allowed these organizations to adapt, refine, and enhance work previously done to improve the emissions characteristics of land-based diesel engines. In addition, ongoing R&D projects studying different technological innovations for improving overall engine efficiency also were found to produce supplemental emission benefits. However, they cannot force vessel operators to purchase or even test this equipment [23, 39, 68, 70, 71, 91, 97, 102, 148, 208-210, 219, 224, 227, 228].

Engines installed on new vessels (2000 and later) meet IMO requirements, but international container carriers are not compelled to purchase or experiment with engines or equipment that go beyond IMO qualifications [23, 39, 68, 70, 71, 91, 97, 102, 148, 208-210, 219, 224, 227, 228]. Retrofitting vessels is a vital part of any long term emission reduction scheme for the MTS, but without additional in-field testing, it will be difficult to analyze performance, understand and initiate critical refinements, or establish a demand for different emission-reducing products.

Subsidies could provide a means for improving this situation and fostering ongoing technical advances by establishing a funding mechanism to offset or decrease the expenses related to field-testing or prototype development of new or retrofit technologies. This kind of program would also impact vessel operators, as it would require the use of their vessels. However, carriers and engine manufacturers have developed a strong and respected partnership through their combined efforts to improve efficiency and cost-savings with container vessels, and the environment in which the engine manufacturers work is such – highly technical, long-term, higher risk, and an established market with few firms – that it is well-suited to facilitate the implementation of a subsidy [12, 26, 45, 97].

4.7.4 Communication

The goal of communication policy tools is to motivate companies to ensure that their management, manufacturing, products and operations are maintained in a manner that supports environmental laws and practices. Section 3.4 above lists environmental management and auditing systems, information campaigns, disclosure requirements, product information and green labels as popular models of communication programs [34, 107, 110, 111, 113, 169]. Because this type of tool is often introduced as a means for identifying products or operational options that have become available or firms who are not using accessible techniques, communication policies have the greatest influence on diffusion. However, as these mechanisms spur on a greater dissemination of environmentally beneficial practices, they also, over the long term, can serve as an important input for ongoing innovations [16, 34, 119, 132, 135, 172, 194].

The international containerized shipping segment functions as an interconnected network, but the programs and approaches designed to foster changes and advances within this system support segmentation and isolation (focusing on certain industry groups) over collaboration. Each of the different participant groups (shippers, carriers, policy-makers, NGO's, etc.) has a diverse knowledge base and set of resources. By not incorporating certain stakeholders, decision-makers lose access to both information and support that could be incredibly useful. Additionally, by not promoting and maintaining communication among stakeholders, there is a greater chance that members will form misperceptions about other groups that could hamper or dissuade progress [16, 29, 34, 36, 105, 110, 128, 138, 139]. Whether introduced as a way to improve intra-industry collaboration, to recognize and help circulate information on successful new technologies, to identify certain stakeholders for their environmental commitments (eco-labels), or to highlight organizations who are not meeting or participating in environmentally-beneficial practices, there are opportunities for the employment of additional communication efforts within this maritime sector.

4.7.5 Covenants

Covenants or voluntary agreements, the last of the policy options, consist of a contract or accord between industry and either government agencies or non-governmental organizations (NGO's) that facilitates a progressive reduction in environmental impacts from identified products or operations within a designated period of time according to specified, mutually conferred targets, but unlike other mechanisms, this type of program grants freedom to the participants to determine the best means for achieving the given objective [16, 34, 107, 110, 111, 113, 169, 170]. With regards to technology, voluntary agreements initially provide the greatest support to diffusion, as firms are unlikely to sign onto a project without having the necessary technologies or techniques available to use. However, overall these types of programs tend to appeal most to innovation-focused organizations who like to stand out within their sector or prove that they are ahead of the curve [24, 34, 35, 132, 135, 172, 184-186, 194]. From a long term perspective, this feature is extremely beneficial, as these are the kinds of groups who are most willing and capable of developing the new inventions and innovations that keep work on a particular issue moving forward.

Because this kind of measure does not provide an industry-wide mandate, there are greater possibilities for free-riding or some other kind of strategic manipulation. But, participants are typically not blind to these factors [16, 34, 107, 110, 111, 113, 169, 170]. Firms who join do so primarily for image and mission related reasons - membership within a covenant is valued because it is a distinguishing feature for those who join early. Additionally, there is evidence that it also simultaneously acts as a pressure for those who choose to abstain [34, 66, 138, 139, 172-174, 176]. As partners increasingly advertise the policy's merits or if the issue becomes more prevalent, companies who originally opted not to enroll may eventually have to follow suit in order to avoid negative repercussions to their business or reputation.

Building a voluntary initiative where emission-reducing technologies are progressively installed on a series of container vessels (new build and retrofit for current fleet) for a quantifiable and certifiable decline in pollutants at a reasonable rate could be an intriguing option for organizations within each stakeholder category. Any reductions obtained would go beyond current requirements, financing could be achieved through established means such as an annual fee or membership dues (and would be likely to be more cost-effective for the degree of environmental gain than that which could be achieved by each organization through independent action), and regulatory agencies could still play a vital, but less intrusive, role as a sponsor and third-party certifier [34, 39, 75, 107, 110, 113, 116, 171, 172, 217]. Today, environmental topics are recognized by a majority of companies, many of whom acknowledge through their corporate annual reports, news releases, and literature that they are looking for ways to strengthen their work in this area. Covenants provide an interesting opportunity to fill the known gaps of environmental standards and stimulate even greater levels of environmental responsibility, environmental technological advancements, and public/private sector cooperation through the creation of agreements designed to promote short-term diffusion and long-term innovation of emission reducing technologies [24, 34, 37, 39, 66, 134, 136, 172, 174, 176].

4.8 Summary

Environmental technologies are regarded as practical and effective means available to the marine transportation industry for addressing the vessel emissions issue [37, 39, 66, 68, 70, 89, 148, 192, 206, 208-210, 224, 225, 227, 228]. Understanding how best to motivate or manipulate the drivers and influences of technology change and also how to incorporate those ideas and principles into the environmental policy-making framework should become a greater focus for policy-makers. This is a complex problem that deserves a more multi-faceted approach, utilizing a broader range of both tools and information to facilitate both near-term and long-term solutions.

Characteristics such as risk acceptance, pace (fast or slow), size, the type of product or process being provided, and competition can all influence a firm's decision to implement or develop environmentally preferred technologies [24, 34, 35, 173, 174, 185, 194, 198]. Within the international container industry, the stakeholders represent a diverse mix of companies and organizations that vary on these elements but, as this chapter demonstrates, no matter where along the technology path particular groups are focused, there are policy opportunities. For example, programs geared at facilitating diffusion and incremental technological change can produce short term individual environmental gains that are often more readily applied to a larger group of participants, thus creating a more significant cumulative impact. On the other hand, initiatives focused on encouraging those companies actively involved in creating inventions and innovation of the radical variety have the capability of generating more substantial industry advances or shifts with much more dramatic long term effects [24, 34, 35, 172, 184-186, 191, 194]. The environmental policy framework for the international maritime industry should be structured and utilized so as to support and pursue both of these paths.

These first four chapters have demonstrated that the three areas of technology, environmental policy, and stakeholders are joined through a critical mix of interconnections and that a realization and better comprehension of the interrelations of those sectors offers an effective way forward for this industry and this issue. To facilitate ongoing reductions in vessel emissions, research and industry actions must move beyond independent concentration on these three areas to more multi-faceted investigations into how the policy-making framework can better join these different elements together. The next chapter will take a closer look at the third and final element – stakeholder objectives. Whatever course of action is selected for the vessel emissions issue, the values that drive participant decisions regarding possible solutions are a critical piece of the policy-making process. Up to this point, much of what is discussed relating to participant values is based on observations or perceptions rather than actual discussions or collected data. Chapter 5 utilizes established methods to begin to push past these assumptions and to begin to build an informed understanding of this significant but lesser known and utilized part of the policy-making framework.

Chapter 5

RESEARCH DESIGN AND METHODS

5.1 Introduction

This chapter presents how approaches from decision analysis can be used to strengthen the present policy framework by investigating different ways to – bring all critical stakeholders into the policy debate, learn what preferences and objectives motivate their actions, and facilitate a more informed approach towards environmental policy-making for the vessel emissions issue. Research focused on empirically analyzing how stakeholder preferences or objectives can impact and enlighten the decision-making process has not been emphasized in the area of environmental policy-making within the MTS – an area where this kind of knowledge would be incredibly useful. This work contends that using tools or techniques to identify, analyze, and discuss stakeholder preferences for emission reduction programs and components of those initiatives provides decision-makers with a standardized, proven, and effective means for accessing stakeholder knowledge that, up to this point, has been largely guided by assumptions. The following sections will go into the area of decision analysis in greater detail and then move on to outline specifically how this research incorporated its techniques through the development of the preference ranking tool. The next chapter (Chapter 6) will present the results from and analysis of the exercise [28-32, 229-234].

5.2 Decision Analysis

The act of making decisions is a process that is utilized so frequently in our daily lives that it often seems more instinctual than conscious and, as such, does not often attract focus or detailed analysis [30, 235]. Depending on both the issue at hand and the type of resolution that is being forwarded, however, the impacts resulting from this practice can be far-reaching. The development of decisions that affect entire communities of people, such as those involved in the creation of public policy, have evolved to become the focus of much greater attention and examination as problems and their effects have become increasingly complex. Topics that find their way onto the policy agenda invariably require decision-makers to formulate a balance between the objectives and impacts for many varying, often conflicting, viewpoints - a situation that, if successful, can serve as a tremendous catalyst for change, but, if not, can quickly dissolve into a powder keg of confusion and criticism [28-31, 108, 110, 111, 235, 236].

Both policy analysis and decision analysis stem from a common background. Each deconstructs a larger process into its respective components to enable the identification of problem areas and to provide insight for a more pragmatic and informed representation of the topic. Policy analysis is defined as the process of determining "which of various alternative policies will most achieve a given set of goals in light of the relations between the policies and the goals" [236]. Decision analysis focuses on establishing a detailed assessment of how decisions with multiple objectives are approached and managed through the utilization of several different qualitative and/or quantitative methods. Decision analysis, therefore, centers on methods for constructing the set of goals and determining options that are representative of all of the parties affected by the issue that can then be used to inform the policy analysis pursuit of selecting appropriate alternatives [28-31, 235, 237, 238].

Decision analysis helps decision makers to identify balanced choices based on clearly articulated stakeholder values. Impasses between parities or the rejection of proposals stem largely from a lack of consensus among groups who are influenced by the decision-making process but who are ignored or discounted during the program structuring period. Determining preferences and objectives arms the decision-maker with a wealth of information that can be very effective in diffusing controversy and building accountability. Decision analysis, therefore, is not designed to provide a "right" answer to a given problem but rather to make the path to determining a solution more open, inclusive, communicative, creative, and educated [28-31, 33, 235, 237].

The area of decision analysis uses a mix of qualitative value and judgment assessments as well as mathematical modeling to help make the decision-making process more transparent and to force those involved to think about and attack the given problem in new ways. It can employ several different types of analytical tools, including social welfare functions, conjoint analysis, behavioral decision theory, mulit-criteria decision-making analysis (MCDM), cost-effectiveness, cost-benefit, multi-objective generalization, and mathematical optimization – among others, to specifically address certain features or to assess the entire decision-making process. Each instrument has distinctive features, making different ones more or less valuable based on the situation at hand. All of them, however, work in their own way to transition what can appear to be striking conflicts in decision objectives into a more equitable, aggregate resource for aiding in the selection of a collective course of action [28-31, 33, 198, 233, 235, 239-241].

5.3 Determining the Appropriate Technique

Incorporating values from multiple participants is challenging. A direct solicitation of values could provide a general picture but would not necessarily provide information relating to trade offs among preferences. Also, debates over values, if not properly structured, can unintentionally create additional tension and setbacks among organizations. For these reasons, it was pertinent to pursue an approach that allowed for a mix of both quantitative and qualitative analyses of stakeholder preferences [28, 30-33, 235, 237, 242].

In order to determine the most appropriate method for this research, the issue needed to be clearly defined - the lack of independent information or data regarding key stakeholders' preferences towards emission reduction programs, the attributes that compromise those initiatives, and a comprehension of the impact of those values in decision-making or trade-off situations. The next step was to identify which technique would offer an efficient, consistent, neutral, reproducible, and productive means for gathering this information.

From the pool of available analytical tools listed in the previous section (5.2 Decision Analysis), one option suited to this kind of work is conjoint analysis (CA). With a dynamic history and connection to several different disciplines, conjoint analysis began as a process used by mathematical psychologists (most notably Luce and Turkey) as "a variety of non-metric models for computing part-worth (attribute-level values) from respondents' preference orderings across multi-attribute stimuli, such as descriptions of products or services" [231, 243]. Believing that the process could also be useful to other areas of study, it was then adapted by consumer researchers for work in assessing consumer preferences for multi-attribute options.

Market analysts apply conjoint theory to create hypothetical choice problems that are consistent with real consumer decisions in order to discover participant values for options and attributes, as well as changes to those features. For this research, this same process could be used to produce hypothetical policy choice trade offs that would be similar to real policy choices. The development and application of this type of approach would be straightforward, and the results could offer a more structured view into stakeholder preferences for emission reduction programs and their components. Discovering what groups need or want in a policy or program, the strengths of their particular preferences, an understanding of the flexibility of those values and a determination of the consistency of those views within and across different groups would be valuable, as each of these factors significantly impacts the policy-making process - from agenda setting to program development to participation [229-234, 241, 244].

5.4 Conjoint Analysis

The foundation for this type of work lies in an analysis of how individuals make complex decisions or "the process of assessment, comparison, and/or evaluation in which consumers decide which aspects of products or services are important, compare products or services on each of the important aspects, and decide which one(s), if any, to choose" [231]. A substantial amount of work on the topic of preference measurement was produced during the late 1960's through the 1970's by researchers and academics in several different areas - mathematical psychology, psychometrics, statistics, econometrics, and operations research. Findings and advancements realized during this time, especially theoretical work on expectancy-value (Fishbein or Rosenberg) and the new economic theory of consumer choice for methods of modeling multi-attribute consumer preferences, heavily influenced the development of conjoint analysis. Thus, the CA method came to represent another means for dealing with participant utility [229-234, 241, 243-245].

Instead of taking a compositional (or componential) approach, where the total utility for an object or program is discovered through a weighted sum of the item or initiative's perceived attribute levels, which are each rated independently by the participant, conjoint methodology pursues a decompositional approach where participants assess a set of "total profile" descriptions [230]. Based on how the profiles are ranked or rated, the researcher is able to determine information regarding a participant's overall preferences for the various attributes, as well as how those preferences are impacted in a trade off situation [230, 231, 234, 241].

Studies issued by Green and Rao in 1971 and Green and Wind in 1973 provided some initial directives on how to model multi-attribute judgments in marketing, but the actual term and process for conjoint analysis was not introduced until a publication by Green and Srinivasan in 1978 [229, 230, 232]. The term "conjoint analysis" was defined so as to include "any technique used to estimate attribute utilities based on subjects' responses to combinations of multiple decision attributes" [230]. Over time, this general characterization has led to the development and implementation of several different methods for performing conjoint research – each with their own assumptions, analysis, and experimental guidelines. This conscious acceptance of flexibility has been widely recognized as one of the greatest strengths of this methodology and has made conjoint analysis an incredibly adaptable and useful tool for numerous different applications and areas of study [230, 231, 234, 240, 246-248].

The original 1978 publication by Green and Srinivasan identified a series of steps for developing a project utilizing conjoint analysis [230].

1. Selection of a model of preference
2. Data collection method
3. Stimulus set construction for the full-profile method
4. Stimulus presentation
5. Measurement scale for the dependent variable
6. Estimation method

Adaptations to these procedures have become accepted as work with the approach has grown, but, for the most part, these basic principles continue to serve as the foundation in all conjoint exercises. These steps are not fixed in their order. Changes in circumstances and objectives or new findings can adjust the progression or serve to suggest a repetition of previous segments [230, 231, 234, 249, 250].

The selection of a preference model, the first step listed, is critical. It is what is used to define the utility for each of the attributes. For conjoint analysis, the mathematical models of preference typically fall into one of the following categories (illustrated in Table 5.1 below) - vector, ideal point, part-worth, or some hybrid combination of the three. The part-worth option is recognized as the most commonly used of the group, but the final decision as to which option to choose is largely based on the type of attributes being used to represent the given problem and how they function. For example –

> One may always prefer greater durability (vector), and smaller waiting time (vector), but may prefer moderate levels of sweetness or size of automobile (ideal point). One may, however, prefer maximum temperature levels for both iced and hot tea and have a lower preference for in-between temperature levels (part-worth function) [230, 244].

None of the preference models have been found to be better or worse for analyzing or capturing utilities. Therefore, the final choice should be based on which one is the best fit for both the problem and the attributes [230, 231, 234, 250].

Table 5.1 The Three Most Common Preference Models used in Conjoint Analysis Exercises

Preference Models		
Part-worth	Vector	Ideal-point
$s_j = \sum_{p=1}^{P} f_p(y_{jp})$	$s_j = \sum_{p=1}^{P} w_p y_{jp}$	$d^2_j = \sum_{p=1}^{P} w_p (y_{jp} - x_p)^2$
P = Number of attributes J = Number of stimuli (levels) used in the study design s_j = The respondent's preference y_{jp} = The desirability of the pth attribute for the jth stimulus (level) f_p = Function denoting the part-worth corresponding to level y_{jp}	P = Number of attributes J = Number of stimuli (levels) used in the study design s_j = The respondent's preference w_p = The respondent's importance weight for each of the P attributes y_{jp} = The desirability of the pth attribute for the jth stimulus (level)	P = Number of attributes J = Number of stimuli (levels) used in the study design s_j = The respondent's preference w_p = The respondent's importance weight for each of the P attributes y_{jp} = The desirability of the pth attribute for the jth stimulus (level) $^{d2}{}_j$ = Preference(s_j) is inversely related to the weighted squared distance d^2_j of the location y_{jp} of the jth stimulus from the individual's ideal point x_p

Source: "Thirty Years of Conjoint Analysis: Reflections and Prospects" (Green, Krieger, and Wind – 2001)

The second and third phases - data collection and stimulus set construction - require that the researcher decide the most effective way for the information to be assimilated and, eventually, presented to the participants. The two options that are most often employed here are either a two-factor at a time approach (also referred to as a trade-off procedure) (Figure 5.1 below) or a full-profile approach (Figure 5.2

below). The first technique provides the respondent with a sample of different pairs of attributes and levels and asks that they be ranked from most preferred to least preferred. In the table below the two items being compared are Brand and Total BTU's. It is easy to implement, can reduce the risk of overloading the individual with information [230], and also works well with mail questionnaire forms [230]. However, this format also has recognized weaknesses. Participants often see it as being less realistic than the full-profile option and can find it confusing when there are numerous factors and levels to rank, resulting in fewer genuine responses [230, 231, 233, 234, 250].

The full-profile method (or concept evaluation task), on the other hand, provides the respondent with a set of stimulus cards to sort or rate based on his or her preferences. Each card represents a complete product, service, or program, characterized by a set of identical attributes, as is outlined in the second figure below where Oven Type and Price have been added to Brand and Total BTU's. Although the attributes remain the same, the levels corresponding to those features change across the different cards – a process that more closely assimilates actual alternatives which have multiple attributes. [241]. This does not mean, however, that the full-profile application is immune to design obstacles. The most critical risks with this approach involve the possibility for information overload and respondent fatigue. Unless these features are accounted for in the design of a full-profile exercise, there is a higher likelihood that respondents will attempt to oversimplify the task, producing answers that are less dynamic than what would have been revealed in reality where additional time, debate, and other motivating factors may have influenced the responses [230, 231, 234, 241].

	Total BTU's		
Kitchen Range Brand	30,000 BTU's	40,000 BTU's	50,000 BTU's
Viking	8	4	1
Wolf	12	9	5
Kitchen Aid	11	7	3
Thermador	10	6	2

Figure 5.1 Example of Two-Factor at a Time Stimulus Set Construction

Kitchen Range X
Brand
Viking
Total BTU's
40,000
Oven Type
Convection
Price
$4000

Figure 5.2 Example of Full Profile Stimulus Set Construction

Stimulus presentation, the fourth item on the list, determines how the information will be offered to the participant. A verbal description, paragraph description, or pictorial representation are the typical formats considered, but, again, the flexibility of the CA design allows for combinations of these, depending on the problem of focus and the needs of the particular research. Of the three, the pictorial representation has been shown to offer slight advantages over the others. It tends to lessen the occurrence of information overload and respondent fatigue (especially in complex decision scenarios), while increasing the perceived level of realism of the exercise [230]. This is not to say, though, that studies employing verbal or paragraph descriptions cannot be successful. As with each of the other steps, the issue, the attributes, and the situation should serve to determine a suitable presentation method [229-231, 234, 241, 250].

The final two items, the measurement scale for the dependent variable and the estimation method, deal with how the respondent's preferences will be ascertained (ranking or rating) and how the collected data will be analyzed. The dependent variable in a conjoint exercise is typically the assessed preference for the particular item, service, or program that is being offered. Participants can share their preferences in CA studies by either ranking (non-metric format) or rating (metric format) the different options that are presented to them. The choice between these two activities is at the discretion of the researcher based on the questions that he or she is trying to answer, the type of item or option being assessed, and the method that would be the most straightforward and easily understood by the respondent [230, 231, 234, 241].

Once the measurement scale has been established, the last step is to determine how this ranked or rated preference data will be analyzed and translated to address the particular research objectives. This is the responsibility of the estimation method. Some of the available options for this phase include: Metric and non-metric regression analysis, MONANOVA, PREFMAP, LINMAP, Non-metric tradeoff, Multiple regression, LOGIT, PROBIT, Hybrid, TOBIT, and Discrete choice. Again, the choice among this group is predominantly guided by the problem itself, the selected preference model, and how the researcher has chosen to measure the dependent variable. Often times, the appropriate type of measurement scale and estimation method naturally emerges as the researcher goes through the process of developing his or her conjoint analysis study. Work utilizing each of these methods over a diverse range of issues has been performed without any option emerging as being more or less effective, a finding that is extremely important and supports the implementation of the CA technique over a broad range of topics [230, 231, 234, 241].

5.5 Development of a CA Exercise for Vessel Emission Reduction Programs

The conjoint analysis approach offered several advantageous features for the type of work that I proposed. By creating hypothetical emission reduction programs through conjoint analysis that the participants could review and rank, it would provide a means for gathering information regarding key stakeholders' preferences towards those types of programs, as well as the attributes that compromise them. Also, by ranking both attributes of potential programs and hypothetical emission reduction programs themselves, the exercise provides a means for studying if or how participant preferences can be impacted in decision-making or trade-off situations. The utilization of conjoint analysis in many similar types of studies (multi-attribute trade-off analysis) provided credibility and recognition for this kind of application, and, finally, the flexibility inherent to the conjoint design made it appealing.

This research proposes that the container industry utilize new approaches for addressing environmental issues such as air emissions, including the introduction and implementation of tools and techniques to help provide organization and structure to what is certainly a very complex decision-making process. For this reason, employing a tool that could readily transition from the academic realm into the field and be able to continue to evolve within the industry beyond this initial effort was important. The above paragraphs provided a streamlined summary of the key points required to build a conjoint analysis study. The following section will explain how I interpreted and customized those steps to produce a preference ranking exercise for analyzing stakeholder values for emission-reduction programs for container vessels.

5.5.1 Selecting a Model of Preference

The one model out of the group of preference models (vector, ideal-point, and part-worth – shown in Table 5.1 above) that is most often found to be the best match to participants' preference decisions regarding attributes is the part-worth model [229-231]. "The part-worth model reflects a utility function that defines a different utility (part-worth) value for each of the levels of a given attribute" [231]. The researcher, therefore, must identify distinct levels to represent each attribute. These levels are differentiated by variables in the design, allowing the analyst to discover the magnitude of impact that each attribute at different recognized levels has on the overall preference designation. "The scaling is common across all attributes; this allows the analyst to add up part-worths across each attribute to obtain the overall (product or service) utility of any profile composed from the basic attribute levels" [231]. In thinking about the types of attributes that might comprise a conjoint technique for vessel emission reduction programs and how participants could react to different levels of change to either environmental or business impacts, the part-worth model emerged as an appropriate preference model for this CA exercise - preferring the maximum levels for certain attributes (big impacts or no or little impacts) with lower preferences for in-between levels [230, 231, 244].

5.5.2 Data Collection Method

The next step was to settle on an effective approach for data collection. Between the two-factor at a time approach or the full-profile approach, the full-profile method was selected for this research. Industry members responsible for assessing or developing schemes for reducing vessel emissions (whether technologically or operationally based) consider and compare options against one another as complete programs rather than by a few attributes at a time. Therefore, using an approach that could produce a series of hypothetical, but realistic, emission-reducing programs for respondents to rank most closely mimicked a real world decision situation for the participants [230].

5.5.2.1 Stimulus Set Construction for the Full-Profile Method

Building a full-profile approach required that I first identify the core attributes that the program would value. In formulating the series of attributes, a significant amount of freedom is granted to the experimenter, as there is not an official or best method for undertaking this task. Both the attributes themselves and the chosen levels are at the discretion of the individual building the CA exercise. However, in order to ensure that an appropriate and meaningful mix is achieved, most analysts employ tools such as focus groups or detailed interviews with individuals familiar with the selected topic before final attribute decisions are made [230, 231, 234].

I also utilized input from an array of industry experts, creating my list of attributes through a layered process. First, I analyzed written work (reports, legislation, meeting notes, etc.) on current emission reduction programs as well as journals and other literature discussing vessel emission initiatives to form an initial compilation of vessel emission policy objectives or program traits. Then, I consulted with representatives from each notable stakeholder category – carriers, shippers, policy-makers, advocates, etc. – who were familiar with the issue to verify and streamline my findings. This work enabled me to formulate a list of specific, actionable attributes that were grounded in both empirical work and real world experience from all of the major players, a plan that also would help to avoid information overload and fatigue. After several iterations, this process produced a selection of seven fully independent program attributes (shown in the first column of Table 5.2 below and also with their definitions in Appendix E) as the most critical components to the decision or policy-making process for initiatives aimed at addressing the vessel emissions issue. These seven attributes are: percent reduction, fixed cost, annual cost, time to adopt, service effects, verifiability, and reduces other emissions.

After finalizing the choice of attributes, the next step was to give the characteristics meaning by assigning them levels or values – either quantitative or qualitative. Much of the legwork for this process occurred as a natural by-product from the debate, analysis, and organization of the above list of attributes. The levels needed to be easily understood, accurate enough to be believable, and different enough to reflect how preferences might change with alterations to the values. It was also important, though, to limit the number of levels assigned to each attribute, as increases in levels per attribute translated into greater complexities in formulating stimulus cards - which will be discussed in the following paragraphs [230, 231, 234].

5.5.2.2 Defining the Attributes

For the purposes of this work, the reduction of nitrogen oxide emissions (NOx) was selected as the main focus, with impacts to both sulfur dioxide (SOx) and particulate matter (PM) emissions serving as tradeoffs. Therefore, the attribute percent reduction equated to percent NOx reduction, and the attribute reduces other emissions meant reductions in SOx and PM. This was done for a couple of reasons. It aligned well with the current international and domestic policy work on reducing vessel emissions so would be familiar to the participants (reducing potential risks for fatigue and confusion). This approach also provided for a diverse array of abatement options to pull from, and, lastly, maintaining a spotlight on one element - NOx reductions - with SOx and PM tradeoffs made the tool more straightforward – easy to understand – while still incorporating enough complexity to feel realistic [231, 240, 241].

A majority of the attributes (time to adopt, service effects, verifiability, and reduces other emissions) were able to be adequately addressed with only two levels. The remaining attributes (percent reduction, fixed cost, and annual cost), however, were more complicated than the others, thus requiring the addition of a third level each in order to provide a more feasible array of options for the participants (see Table 5.2 below). Several studies and publications note that respondents, "can almost always evaluate at least eight attribute combinations as long as the levels do not consist of long verbal descriptions, complex pictures or models" [231]. The selection of seven attributes with limited and very straightforward levels, therefore, was a design that was supported by CA literature and research [230, 231, 234, 250].

Table 5.2 Preference Ranking Exercise Attributes and their Levels

Attributes	Level 1	Level 2	Level 3
% Reduction	15%	50%	90%
Fixed Cost	$0.00	$100,000	$300,000
Annual Cost	$25,000	$50,000	$75,000
Time to Adopt	Next Yard Visit	Immediate	
Service Effects	None	Revision to Current Logistics	
Verifiability	Calculated Certification	Monitored Certification	
Reduces Other Emissions	No	Yes	

5.5.2.3 Implementing the Full-Profile Approach

The next step involves transforming the above attributes and levels into hypothetical programs, or stimulus cards, by implementing the full-profile approach. The full-profile approach follows a full-factorial design, which means that the number of possible options quickly grows as the attributes and their levels increase. For example, a project that has three attributes at three levels each and two attributes at two levels each creates a total of 108 possible descriptions ($3^3 * 2^2 = 108$) [230, 241]. One recognized way of combating this issue and effectively limiting the number of possibilities to a more reasonable sampling is to use a fractional-factorial design [229-231, 241, 245]. "A fractional-factorial design involves testing a subset of all possible combinations of the factors" [230].

This method can estimate the main effects (single-factor effects (and, in some cases, selected interaction (two-factor) effects) without confounding and the "sacrifice in information obtained is balanced by the reduced resource requirements compared with a full-factorial design" [251]. A fractional-factorial design is normally recommended for studies when only analysis of the main effects are desired and when there is not a considerable amount of environmental correlation between some or all of the attributes (for example, “the attributes of - 0-55 mph acceleration time, gas mileage, horsepower rating, and top speed have high environmental correlation” [230]). Both of those elements applied in this situation so a fractional-factorial design was deemed appropriate for this research [230, 241].

There are numerous “design of experiment” (DOE) software options available in the market today that are capable of producing a fractional-factorial design. Based on the desired objectives of this work, the availability of the software, and the success with the technique in other similar types of research designs, the decision was made to utilize a program from Quality American – an application that uses the Taguchi method (the application of orthogonal arrays for experimental design) to create the fractional-factorial design needed for this proposed full-profile exercise [231, 251-253].

In the early 1980’s, Dr. Genichi Taguchi developed techniques for using experimental design to streamline and improve characteristics, products, and operations. These Taguchi methods produced significant results in quality engineering or process capability (PC) projects and, eventually, began to find areas for application outside of the engineering world [239, 251-253]. Taguchi used orthogonal arrays, “which had previously been used to reduce experimental bias, as a design tool for determining the influence of each variable under study on both the mean result and the variation from that result” [251].

> The primary advantage of orthogonal arrays is the relationship among the factors under investigation. For each level of any one factor, all levels of the other factors occur an equal number of times if symmetric

(equal levels for all factors) or with proportional frequencies if asymmetric (different number of levels among the different factors). This constitutes a balanced experiment and permits the effect of one factor under study to be separable from the effects of other factors [251].

Following the Taguchi process for experimental design, therefore, a much smaller, but still incredibly effective group of options is constructed with results that are reproducible [239, 251-253].

The seven attributes identified in Table 5.2 above and their designated levels (four with two levels and three with three levels) would have created a very large group of stimulus cards with a full-factorial approach ($2^4 * 3^3 = 432$). Taking advantage of the benefits of a Taguchi style of experimental design to create a more reasonable fractional-factorial collection of emission reduction programs for a full-profile ranking experiment, the attributes and their levels were entered into the computer software program from Quality American - *Taguchi method by Ranjit Roy* (1990 DOE-PC IV). The program was able to efficiently evaluate the hundreds of possible unique combinations of attributes and levels and present a set of alternatives most soundly capable of determining the main effects. This group of 11 options (or stimulus cards) - out of the original pool of 432 - served as the emission reduction program options for the preference ranking exercise. These cards, designated by different colors, are presented below in Table 5.3 [253].

Table 5.3 The 11 Program Options Produced for the Preference Ranking Exercise

Card Color	% Reduction	Fixed Cost	Annual Cost	Time to Adopt	Service Effects	Verifiability	Reduces Other Emissions
Yellow	90%	$100,000	$75,000	Immediate	None	Monitored Certification	Yes
Purple	90%	$100,000	$75,000	Next Yard Visit	Revision to Current Logistics	Monitored Certification	No
Blue	90%	$0.00	$50,000	Next Yard Visit	Revision to Current Logistics	Calculated Certification	No
White	90%	$300,000	$50,000	Immediate	None	Calculated Certification	Yes
Pink	50%	$100,000	$25,000	Immediate	Revision to Current Logistics	Calculated Certification	No
Red	50%	$300,000	$75,000	Immediate	Revision to Current Logistics	Monitored Certification	Yes
Orange	50%	$300,000	$50,000	Immediate	None	Monitored Certification	No
Black	15%	$100,000	$50,000	Next Yard Visit	None	Monitored Certification	Yes
Charcoal	15%	$0.00	$25,000	Next Yard Visit	None	Calculated Certification	No
Maroon	15%	$300,000	$75,000	Next Yard Visit	Revision to Current Logistics	Monitored Certification	No
Khaki	15%	$0.00	$75,000	Immediate	None	Calculated Certification	Yes

5.5.3 Exercise Stimulus Presentation, Measurement Scale, and Methods for Administration

With the stimulus cards complete, the next step required that I determine how the information would be explained to the participant – stimulus presentation. The pictorial representation, despite its slight advantages over the verbal and paragraph descriptions, would not be an effective option for the attributes selected for this research. The question, then, over how best to present and run the exercise led to the creation of a verbal description and background component that would be supplemented with a small amount of written material - the stimulus cards themselves and a sheet of definitions for each of the attributes and their levels. To make the preference ranking exercise both more effective and interesting, I chose to conduct it through in-person encounters, either within meetings with several participants or through one-on-one interviews, rather than through a mailed survey format [230, 231].

Ensuring clarity and ease of comprehension within the verbal description (shown in its entirety in Appendix D below) was extremely important, as it “framed” or set the stage for the participants. The two most important risks that had to be mitigated in using this approach were information overload and respondent fatigue. As a means to address both of these potential hazards, the description provided additional information on the attributes and their levels to help refine the definitions, and the process for completing the exercise was kept open to questions, comments, and dialogue to help make the procedure more interesting, stimulating, and enjoyable. These two features together with the analysis and industry input used for the tool’s attribute development (making certain that only core, rather than secondary or overly specialized, elements were being valued) helped to defend against both information overload and fatigue. In order to maintain uniformity, the same verbal description script would be administered with every participant [230, 231, 234].

Developing the description was also critical because it allowed me to concentrate on how best to utilize the tool to attain the most valuable policy-focused information. One option for reducing vessel emissions that is increasingly being investigated or pursued is voluntary, industry-based initiatives designed to motivate change beyond current regulatory requirements. Indicators within the international container industry (which were discussed in sections 3.5, 3.6, and 4.7 above) suggest that this is an option with a great deal of potential, but, research and information regarding actual stakeholder values for this type of alternative is limited. Therefore, utilizing the formation of the 11 hypothetical initiatives to evaluate stakeholder preferences for voluntary vessel emission reduction initiatives would add a new layer of information to the work [37, 38, 40, 75].

Because respondents would be told in the verbal description that this research was built with the objective of considering possible designs for a voluntary vessel emission reduction program, it was explained that they would only want to participate if the programs would have value to their organization – thus giving them the option to not participate if there was no preference for or desire to participate in voluntary programs. [230, 234].

At this point, it also became necessary to determine which measurement scale to use. As was noted in section 5.4 above, this scale typically follows a non-metric (ranking or paired comparisons) or metric (rating) plan. Because the objectives of this research are to determine if decision-aiding tools, like Conjoint Analysis, can be used as a productive means to incorporate various stakeholders into the policy process and to assess if they can provide insights to the policy-making process, the ranking (non-metric) approach was more suitable for the work than a rating (metric) plan. The goal for this work was not to determine the “best” policy option (which would support rating) but rather to understand more broadly the objectives and preferences of different stakeholder groups for various attributes and program options [231, 241]. Ranking a series of hypothetical vessel emission reduction programs from most to least preferred is a process that would be straightforward, easily understood by the respondents, and capable of being completed in a timely manner - three features that would help to keep the data collected consistent [230, 231, 234, 241].

Based on how the 11 cards were arranged (from most preferred to least preferred), this approach could provide data on participant preferences from one perspective. However, supplementing the exercise with some additional tasks - a perceived consistency check for the respondents on their first and last program choices, a direct attribute assessment, and a second run of the exercise attempting to assume another group’s perspective - would allow for the collection of a larger and more detailed range of stakeholder preference data [230, 231, 234].

The request that the participants estimate and share what percentage of individuals within their group they think would agree with the technique that they chose for their first and their last choice provides insight into the level of confidence that individuals feel exists for particular types of programs within their organization (as well as other like-minded organizations). These estimations could then be compared to the quantitative results to evaluate perceptions against actual choices.

The direct attribute assessment could also serve as a means for analyzing the similarities and differences between direct statements of value and decisions involving trade-offs of those values. By directing respondents to arrange the seven attributes in order of their group's preference (most preferred to least preferred), one view of their values is presented. That information can then be judged against the order of the attributes that is revealed from how the cards have been ranked as a way to gauge flexibility and consistency in factor preferences [230, 234].

Finally, the task of completing the exercise a second time assuming another stakeholder's perspective was included to expose how well the participants comprehend other industry views and to force them to look at the problem from a different perspective. Understanding what you and others like you are looking for in environmental programs is certainly essential, but, in a situation where negotiations among different groups are necessitated to facilitate change, having an accurate assessment of the preferences of the other organizations involved is also imperative [28, 29, 33, 235, 242].

The exercise, in its entirety, is composed of a series of steps. First, the individuals are provided with an envelope containing: a set of 11 stimulus cards (arranged in random orders), a sheet explaining the attributes and their levels in detail, and a double-sided response form designed to accommodate all of the required respondent data. The framing or verbal description serves as the introduction for the participants to the exercise. It explains the overall purpose and provides the necessary instructions and information needed to clarify and help familiarize the respondents with the attributes that they are going to be asked to consider both in programs and individually. This section also queries participants for basic demographic data – age, number of years in the industry, etc [230, 234].

The ranking of the 11 stimulus cards (most preferred to least preferred), based on the preferences from each group's own perspective, serves as the next phase. This was the lengthiest part of the process, so was undertaken closer to the start to avoid fatigue. Additionally, because all of the subsequent steps of the exercise utilized the same components as this process, it aided in making the respondents more comfortable and familiar with the attributes, the cards, and the ranking procedure so that the successive ranking of attributes and cards, even from a different perspective, was well understood and went rather quickly [230, 231, 234].

The first card ranking was followed by a perceived consistency check on the participant's first and last card choice. This step involved simply asking the respondent to note on the response form what percentage of individuals within his/her same group that he/she thought would agree with the program that he/she selected first and last. Next, the individuals were instructed to rank the 7 attributes (from most preferred to least preferred) based on their group's perspective and preferences. After the cards and the attributes had been sorted once, the final phase of the exercise requests that the participants adopt another viewpoint and, again, undergo a ranking of the cards, a consistency check, and an attribute ranking from this perspective.

Asking the respondents to assume a different perspective provides interesting insight into how well individual entities within this industry actually know one another with regards to the issue of vessel air emissions. From a policy standpoint, this kind of information serves numerous, valuable purposes. For example, if the organizations revealed that they each possessed a solid understanding of other industry views and preferences, then placing a focus on creating working groups geared towards developing and implementing some kind of emission-reduction initiative would be a productive result. Establishing programs or initiatives for improving education or for gaining a better understanding of the players and the issue, on the other hand, would be a waste of resources as the organizations had proven to be beyond this phase [33, 235, 242, 254].

Overall, a better comprehension of how groups within the same industry perceive one another and their views and preferences can provide many advantages. It can uncover places where there are misunderstandings or misperceptions among groups that could be damaging to or preventing forward movements. It can also highlight areas that may have been previously overlooked that offer notable potential for action. This kind of work can provide meaningful feedback for both the formulation and implementation of programs. The results act as a quantitative baseline for an influential feature that is usually perceived as being qualitative – values or preferences. By establishing this starting point, it then becomes possible to move forward on this issue with a transparent map of where the groups have been. Changes can be made as needed to the exercise, attributes, or levels based on what the findings or outside situation reveal. In this way, the technique becomes a tangible way for stakeholders to gauge progress on the topic and for policy-makers to establish a clearer understanding of how various incentives or requirements would be likely to work or how organizations may react [30, 33, 198, 235, 242, 254].

Including a second run of the exercise assuming another group's perspective made it necessary to determine what the alternative viewpoints would be. The carriers, or vessel operators, as the group most directly impacted by any proposed changes to equipment or operations for reducing vessel emissions, were selected as one alternate perspective to gauge how other stakeholders view this group. In determining an alternative perspective for carriers to assimilate, the shippers were selected as the alternate viewpoint. The shipper group, or cargo owner, serves as the driving force for the carriers. The two seem to understand each other very well with regards to business matters, but how they relate to each other on environmental topics is less clear. The shippers contribute to the emissions problem, as it is their cargo that the carriers are moving, but they are, as of yet, an industry player that has not been brought to the table on this issue. Incorporating their viewpoint would be an interesting opportunity. Introducing additional points of view beyond the carrier and the shipper seemed to risk making this portion of the exercise overly burdensome and confusing, thus the alternative perspectives for the respondents were limited to these two entities [12, 14, 15, 26].

From start to finish, the exercise took approximately 20 to 30 minutes to complete. One feature that greatly impacted the efficiency of the process was the design of the stimulus cards. Each program, with its accompanying attributes and levels, was printed individually onto narrow cards similar in size and shape to a bookmark. The respondents could, therefore, easily lay the cards out in front of them and move them around quickly until the final ranking order had been determined. This aspect was highly praised by the participants, as it made the process of comparing the varying levels of attributes on the different cards easier and less tiring. A copy of the 11 stimulus cards, along with the full exercise script, response sheet, and attribute definitions can be found in the appendices below.

5.5.4 Determining the Sample and Facilitating Collection

Each of the steps integrated into the exercise gathers information on preferences for voluntary vessel emission reduction programs from several different angles, but, making the tool as effective as it could be, also relied on ensuring that all of the critical stakeholder groups were represented in the sample population. Decision theory recommends that all stakeholders who will be impacted (or represent individuals or entities who will be influenced) by the policy choice should be included in the policy process. This concept is strongly reinforced by research showing that discounting or ignoring this step often results in an impractical level of confidence in the knowledge of a single or a small group of stakeholders and, in the end, detrimental opposition to the final result [28-31, 235, 237].

In selecting groups or individuals that would become my sample, this decision theory background was used as a guide. First, I outlined which organizations would form the overall collection of stakeholders. Chapter 2 defined in detail the different organizations involved in the world of international containerized shipping and their role or influences on the vessel emissions issue. In order to determine an industry-wide understanding, the work needed to include not only the carrier and policy-making entities who have typically been the focus, but also shippers and various advocacy groups, players who have significant industry influence but who may not have yet been fully drawn in to the policy-making process.

The pool of representatives that encompassed all of the critical industry perspectives (and provided a realistic, distinctive, and well-balanced sample) was a consortium of individuals from: the top 20 container vessel operating companies (Carriers), the top 50 U.S. importers of containerized cargo (Shippers), environmental and trade advocacy groups involved with the marine vessel emissions issues (Advocates), academics who study and perform research dealing with marine vessel emissions (Advocates), individuals from government agencies - such as maritime agencies and environmental agencies at the state and national levels (Policy-makers), and major container sea ports that promote and design environmental maritime policies (Policy-makers). These groups represent the core of the industry and would be the entities most involved in designing and/or implementing industry policy [12, 14, 15, 26, 204].

Prior to implementing the preference ranking exercise, I did apply for and receive approval for the work in line with the University of Delaware's human subjects requirements for this type of research. My letter to the Human Subjects Review Committee requesting an exemption in association with the second category - the use of survey or interview procedures - (found in its entirety in Appendix F below) and approved by Dr. T. W. Fraser Russell, the then acting Vice Provost for Research, clearly outlines the limitations that I adopted and enforced for the protection of my respondents. Namely, that this work does not seek to evaluate individuals themselves, but to characterize the perspectives of different stakeholder views within this industry.

After finalizing which groups would form my sample, the next steps were to determine the appropriate individuals for and size of my sample. Gathering preference ranking data from all of these groups in person was an extremely complicated task, due to the large number and diverse locations of the companies or organizations involved and the fact that they do not necessarily interact regularly, if at all (making the collection process very piecemeal). In an effort to streamline my data collection but still capture a diverse mix of respondents, I focused on soliciting representatives who were identified as decision-makers within their organizations for business and/or activities involving the vessel emissions issue. These decision-makers are held accountable for making the choices that represent and guide their organization's objectives in certain area, which means that they must be well versed and educated on their own group's goals and limitations, as well as the particular issue or area in which they are working.

For the purposes of this work, I felt that it was especially important to target individuals who are considered decision-makers with regards to activities relating to the vessel emissions issue. Any policy-making activities associated with these organizations would necessitate the involvement of men and women in these positions, and directing the exercise at these decision-makers also ensured that the premise and components of the tool would be comprehensible, as the representatives were already knowledgeable on the subject. This served to reduce my total sample population in size but in a way that is supported by sampling principles in decision theory - where smaller groups of highly informed individuals are favored to large numbers of participants with less knowledge or experience with the identified topic [28-31, 109]. Although this approach did decrease the number of people that I would seek out, it did not, however, negatively impact the diversity of the sample overall, as can be seen in Table 5.4 below. The goal was to obtain 30 preference ranking exercise responses from each of the stakeholder groups: Shippers, Carriers, Policy-makers, and Advocates, with the collection of at least 10 to 15 from each group as the desired minimum.

Table 5.4 Participant Information – Average Age, Average Number of Years in their Industry, and the Organizations Represented

	Carriers	Shippers	Policy-Makers	Advocates
Total Number of Participants	29	12	18	13
Average Age of Participants	48.4	43.1	41.1	38.8
Average Number of Years of Experience in their Industry	21.3	17.6	9.3	9.5
Organizations Represented	Maersk Line MSC Hapag Lloyd CSCL Evergreen NOL/APL NYK MOL OOCL Yang Ming ZIM Hamburg Sud	Home Depot Sears Holding Corp. Dole Food Chiquita Brands Int'l. IKEA International Nike Williams-Sonoma Toyota Mattel Del Monte Nissan North America	U.S. EPA MARAD (Maritime Administration) CARB (California Air Resources Board) SCAQMD (Southern California Air Quality Management District) Port of Los Angeles Port of Long Beach Port of Houston Port of Oakland Port of Corpus Christi	Bluewater Network Coalition for Clean Air (CCA) NRDC (Natural Resources Defense Council) BSR (Business for Social Responsibility) PMSA (Pacific Merchant Shipping Association) Independent Consultants University of Delaware Independent Lobbyists for Carriers Independent Environmental Lobbyists

To improve the efficiency of my data collection activities, I initially targeted situations, such as meetings or conferences, where I had a greater chance of gathering data from numerous individuals at one time. Because I focused on men and women with decision-making responsibilities affecting the vessel emissions topic within each of the different categories – Shipper, Carrier, Advocate, and Policy-makers, I concentrated on seminars or engagements devoted to air quality issues and, specifically, vessel emissions problems. These forums typically were developed, run, and attended by people who met the decision-maker qualification. Some of these gatherings were open to supporting outside research, and I was invited to conduct the exercise. During these sessions, I always offered to share the results from the group after the tool had been run. The exercise itself and the summary afterward always proved to be of great interest to the group and certainly prompted numerous discussions. However, I also was denied from collecting information on several different occasions. For this reason, I had to pursue one-on-one interactions with individuals from the various stakeholder groups as well. Although much less productive from a quantity standpoint, these independent interactions were also very dynamic. The combination of these approaches resulted in a total sample population of 72 participants – 29 Carriers, 12 Shippers, 18 Policy-makers, and 13 from Advocacy organizations.

5.5.5 Determining the Estimation Method

With the overall research design and data collection plan complete, the final phase involved determining how best to translate and analyze the accumulated preference rankings – the estimation method [231, 234, 241, 250]. To facilitate the selection of the technique that would fit best with the objectives of this research, I first developed a list of questions to investigate through the results of the preference ranking exercise.

5.5.5.1 Research Questions:

1. What attributes of programs (or types of programs) do different stakeholder groups seem to value most and least – What is important to whom?

    a. What kinds of change do stakeholder groups seem to believe is feasible?

2. Based on the exercise, how well do Advocates, Shippers, and Policy Makers know Carrier's preferences for attributes and programs?

    a. How well do Carriers know Shipper's preferences for attributes and programs?

3. Does an understanding of a (another) group's attribute preferences translate into an understanding of (their) program preferences?

    a. How do the direct attribute ranks translate into program ranks?

    b. Do the different stakeholder groups understand how flexible the attributes are – how open groups may be to negotiating changes – are there potentially misperceptions?

In order to answer these queries, the tool needs to: assess the value that different stakeholder groups have for vessel emission reduction programs and their attributes, formulate a better understanding of the interactions of these preferences, and provide a more precise and informed means for predicting participant actions or reactions to different policy options. Regression analysis, one of the techniques within the group of available estimation methods, aligned well with this style of research and could achieve these objectives [231, 234, 241, 250, 255-258].

Multiple linear regression scrutinizes how independent variables (also called explanatory or predictor variables) relate to a dependent variable (often labeled a response or criterion variable). It is a well known methodology that is straightforward, relatively uncomplicated to implement, reproducible, and readily applicable with common software programs. In this exercise, the dependent variable (y) would be the assessed preference (or rank) for vessel emission reduction programs, and the independent variables (x_1, x_2, x_3, etc.) correspond to the seven attributes and their levels [255-259].

The following regression equation serves as the overarching model for this type of analysis.

$$y = a + b_1 * x_1 + b_2 * x_2 + \ldots b_p * x_p$$

In this equation, the x-values are known (the attributes, in this case), a represents the constant or intercept, and b is the slope (often referred to as the regression or b coefficient). Both the intercept and the regression coefficients are estimated from the data collected from the sample, typically through the least squares method. The regression coefficients are of particular interest, as they denote the contribution that each independent variable makes to the dependent variable. Because each of these valuations are used to determine how the dependent and independent variables impact one another, it becomes possible for the analyst to determine how changes in x-values would influence the y variable for the sample population [255-259].

5.5.6 Creating the Spreadsheet

Using a spreadsheet format, the program card ranks were transitioned into a data set appropriate for multiple linear regression analysis. Microsoft Excel, through its statistics functionalities, has the capability to quickly and accurately perform the necessary regression calculations, and, because of its widespread availability, also serves as an approachable method for bringing this kind of research and its results from the academic realm into the industry [259].

Each different card has a unique selection of levels for its attributes. The total number of available ranks does not change, but the orders (best program to worst program) do change from one participant to another based on the preferences for attribute levels on particular cards. In order to differentiate among the cards and the levels of the different attributes, each level for each attribute was represented by a design code or dummy variable denoting its value - 0 for the lowest value, 1 for the middle value, and 2 for the highest value (displayed in Tables 5.5 and 5.6 below). These values produced a unique series of estimates for every hypothetical program and served as the basis for the regression calculations [231, 234, 241, 258, 260].

Table 5.5 Preference Ranking Exercise Attributes and their Levels

Attributes	Level 1 (0)	Level 2 (1)	Level 3 (2)
% Reduction	15%	50%	90%
Fixed Cost	$0.00	$100,000	$300,000
Annual Cost	$25,000	$50,000	$75,000
Time to Adopt	Next Yard Visit	Immediate	
Service Effects	None	Revision to Current Logistics	
Verifiability	Calculated Certification	Monitored Certification	
Reduces Other Emissions	No	Yes	

Table 5.6 Program Cards with Designations for Attribute Levels

Available Ranks	Programs (Cards)	% Reduction	Fixed Cost	Annual Cost	Time to Adopt	Service Effects	Verifiability	Reduces Other Emissions
1	Black	0	1	1	0	1	1	1
2	Blue	2	2	1	0	0	0	0
3	Charcoal	0	2	2	0	1	0	0
4	Khaki	0	2	0	1	1	0	1
5	Maroon	0	0	0	0	0	1	0
6	Orange	1	0	1	1	1	1	0
7	Pink	1	1	2	1	0	0	0
8	Purple	2	1	0	0	0	1	0
9	Red	1	0	0	1	0	1	1
10	White	2	0	1	1	1	1	1
11	Yellow	2	1	0	1	1	1	1

The spreadsheet consisted of two independent sheets, one for the information from each group's own perspective and the other with data from the alternate viewpoint, for each industry group (Carrier, Shipper, Advocate, and Policy-maker). On both of the sheets, the colors representing the various emission reduction programs were entered according to the respondents' rankings along with the direct orderings of the attributes themselves and the percent of individuals perceived to agree with the first and last card choice. As the colors were inserted, the program automatically inputted the designated codes for each of the cards, thus calculating the b or regression coefficients. The direct attribute rankings, although not needed for the regression analysis, were also an important feature. Those were tracked and entered as well so that they could later be examined and compared to the inferred placement discovered from the card ranking analysis.

Although Excel has a number of available and suitable statistical applications for this kind of research, I chose to use the LINEST function because of its ability to calculate and present an array of regression statistics. LINEST was developed specifically to facilitate regression studies and can evaluate the effects of numerous independent variables. It calculates the values for the constant a (intercept) as well as the regression coefficients (slope or b coefficients) through the least squares method. Additionally, this function produces the standard error value (for the coefficients and for the constant b), the coefficient of determination, the F statistic, the degrees of freedom, the regression sum of squares, and the residual sum of squares. These estimates are each used to help test the goodness of fit and statistical significance of the data, as well as to explain the relationship between the dependent and independent variables, including acknowledgement of which attributes are the most critical to the various groups based on how the cards or programs are ranked [255-260].

5.6 Summary

By providing a clear, structured, and reproducible means for identifying both the effects and the evolution of the environmental, economic, and operational preferences of the affected parties for the vessel emissions problem, this kind of tool produces valuable information for policy development - regardless of type (regulation, covenant, communication, etc.) or level (international, national, or industry-based) [30, 33, 198, 235, 242, 254]. The next chapter will discuss the results of the regression analysis.

Chapter 6

ANALYSIS OF RESULTS FOR THE PREFERENCE RANKING EXERCISE

Analysis of the respondents' program ranking data set required a series of steps to evaluate not only the participant preferences but also the design of the exercise itself [231, 241, 250, 256, 258]. This section begins with an evaluation of the direct rankings of the programs and the attributes to acquire an understanding of the different stakeholder viewpoints and then moves into the analysis of the inferred rankings and tool design – tests for statistical significance.

6.1 Introduction

Going into this research, my knowledge of and interactions with the various stakeholders led me to speculate that the preferences for the seven attributes would differ significantly among the participant categories and that this, in turn, would lead to notable variations in program rankings from group to group. This sentiment was also echoed by industry contacts and respondents when the premise of the tool was explained. The results, however, of the direct attribute and program rankings challenged that initial hypothesis by revealing an unexpected amount of consistency in the preferences of the stakeholders.

Table 6.1 below shows the order of attributes most frequently provided by individuals within each of the different stakeholder categories when asked to rank the attributes from most to least preferred – from their own perspective. Table 6.2 presents the program rankings most frequently supplied by individuals within each participant category when asked to list the cards themselves (the programs) from most to least preferred – from their own perspective. As a reference, Tables 5.3, 5.5, and 5.6 above detail the program options (by color), including the attribute and level designations.

Table 6.1 Direct Attribute Ranking Results (Groups ordering from their own perspective)

Direct Attribute Rank				
	Carriers-Carriers	Advocates-Advocates	Policy Makers-Policy Makers	Shippers-Shippers
1	Fixed Cost	% Reduction	% Reduction	% Reduction
2	Annual Cost	Reduces Other Emissions	Reduces Other Emissions	Fixed Cost
3	Time to Adopt	Fixed Cost	Annual Cost	Service Effects
4	Service Effects	Time to Adopt	Fixed Cost	Annual Cost
5	% Reduction	Annual Cost	Time to Adopt	Reduces Other Emissions
6	Reduces Other Emissions	Service Effects	Verifiability	Time to Adopt
7	Verifiability	Verifiability	Service Effects	Verifiability

Table 6.2 Direct Program Ranking Results (Groups ordering from their own perspective)

Direct Color Rank				
	Carriers-Carriers	Advocates-Advocates	Policy Makers-Policy Makers	Shippers-Shippers
1	Yellow	Yellow	Yellow	Yellow
2	Blue	White	White	White
3	White	Blue	Blue	Khaki
4	Khaki	Purple	Purple	Red
5	Charcoal	Red	Red	Blue
6	Purple	Pink	Orange	Orange
7	Pink	Orange	Pink	Charcoal
8	Black	Black	Khaki	Purple
9	Orange	Charcoal	Black	Black
10	Red	Khaki	Charcoal	Pink
11	Maroon	Maroon	Maroon	Maroon

6.2 Analysis of Direct Program and Attribute Rankings – From Own Perspective

Tables 6.1 and 6.2 list the most common order provided by the four participant categories when directed to rank the eleven programs, designated by color, and the seven attributes from most to least preferred based on their own group's perspective. The differences present in the attribute positions do accurately reflect the role and objectives of each of the different groups both within the industry and with the vessel emissions issue itself. Vessel operators, based on the options picked as the top four attributes, are predominantly concerned with the operational impacts of possible programs. Advocates and Policy-makers, on the other hand, are most strongly driven by societal effects like environmental and health matters but are not resistant to acknowledging that attaining reductions comes at a price. Finally, the Shippers also indicate that they are motivated by societal impacts, with the placement of percent reduction as first, but, as critical players in global logistics, they are also influenced by operational features, such as potential changes to costs and services.

Considering the differences in perspectives and objectives revealed by the attribute orders, the collective results from the program ranking were unexpected. Despite the variations in attribute preference, the four groups selected the same options as their first and last choices. Advocates, Policy-makers, and Shippers shared identical first and second programs, and the Carriers agreed with the Advocates and Policy-makers on the make-up of the top three positions. Although there was variability in the programs occupying slots four through ten, the agreement for the perceived "best" and "worst" options suggests that there is a notable amount of common ground between the groups. The ability to identify areas of concurrence is recognized as an asset when dealing with organizations representing alternative views on a contentious topic, as it provides a starting point for discussion, facilitating negotiation, and building trust [28, 31, 33, 198, 242, 254].

Again, the results and observations presented in sections 6.1 through 6.4 represent an introductory and basic examination of the rankings that were, on average, those most consistently provided by the groups and are meant to help the reader to acquire an initial feel for each of the different stakeholder viewpoints. Section 6.5 will explore the statistical significance of these results.

6.3 Stakeholder Perceived Agreement on First and Last Card Choices

After the initial ranking of the cards, the participants were asked to estimate and share what percentage of individuals within their stakeholder category that they thought would agree with the technique that they had chosen for their first and their last choice (shown in Table 6.3 below). This step was included as a cursory gauge of the level of perceived intra-group consistency. As it was based on individual perceptions, this was more of a qualitative, rather than quantitative element. The Advocates, Policy-makers, and Shippers communicated a sense of strong agreement for their first choice, while the Carriers' estimates were more moderate. With regards to the option placed last, the situation was reversed. The Carriers actually showed that they thought that a greater number of vessel operators would select the same last choice, while each of the other stakeholders offered lower values.

Table 6.3 Within-group Consistency Check - Participants' Estimation of Agreement for the First and Last Program Choices

	Would agree with first card	Would agree with last card
Carriers-Carriers	54%	58%
Advocates-Advocates	80%	79%
Policy Makers-Policy Makers	72%	63%
Shippers-Shippers	72%	62%

6.4 Analysis of Direct Program and Attribute Rankings – From Alternate Perspective

The second part of the preference ranking exercise provides a baseline assessment of how well the stakeholders currently understand each others' preferences for vessel emission reduction programs and attributes. There is a level of consistency in program preferences when sorting from their own perspective, in spite of the variations in attribute values. It is unknown if the organizations believe that areas of agreement are present. By requesting that the respondents rank the programs and attributes a second time, assuming an alternate perspective, this matter can be further investigated.

Tables 6.4 and 6.5 present the most common ranking of program attributes for one perspective (for example Carriers thinking as Carriers (Carriers-Carriers) or Shippers thinking as Shippers (Shippers-Shippers) and then compare that listing to the most common placement offered by the other stakeholder groups when assuming that perspective (for example Advocates thinking as Carriers (Advocates-Carriers). Tables 6.6 and 6.7 take the same approach – comparing the direct rankings gathered from the respondents - but this time for the programs themselves. Table 6.8 gives the details of the cards or programs that were designated as the top three choices and, for a complete look at all 11 programs or cards, Table 5.3 above lists each by color with a full description (attribute and level designations).

Table 6.4 Comparing the Direct Attribute Ranks among the Stakeholders (1)

Direct Attribute Rank - Comparing Perspectives				
	Carriers-Carriers	Advocates-Carriers	Policy Makers-Carriers	Shippers-Carriers
1	Fixed Cost	Fixed Cost	Fixed Cost	Fixed Cost
2	Annual Cost	Annual Cost	Annual Cost	Annual Cost
3	Time to Adopt	Service Effects	Service Effects	Service Effects
4	Service Effects	Time to Adopt	% Reduction	% Reduction
5	% Reduction	% Reduction	Time to Adopt	Time to Adopt
6	Reduces Other Emissions	Verifiability	Verifiability	Verifiability
7	Verifiability	Reduces Other Emissions	Reduces Other Emissions	Reduces Other Emissions

Table 6.5 Comparing the Direct Attribute Ranks among the Stakeholders (2)

Direct Attribute Rank – Comparing Perspectives				
	Carriers-Shippers	Shippers-Shippers	Carriers-Carriers	Shippers-Carriers
1	% Reduction	% Reduction	Fixed Cost	Fixed Cost
2	Service Effects	Fixed Cost	Annual Cost	Annual Cost
3	Fixed Cost	Service Effects	Time to Adopt	Service Effects
4	Annual Cost	Annual Cost	Service Effects	% Reduction
5	Time to Adopt	Reduces Other Emissions	% Reduction	Time to Adopt
6	Reduces Other Emissions	Time to Adopt	Reduces Other Emissions	Verifiability
7	Verifiability	Verifiability	Verifiability	Reduces Other Emissions

Table 6.6 Comparing the Direct Program Ranking Results among the Stakeholders (1)

Direct Color Rank - Comparing Perspectives				
	Carriers-Shippers	Shippers-Shippers	Carriers-Carriers	Shippers-Carriers
1	Yellow	Yellow	Yellow	Charcoal
2	White	White	Blue	Khaki
3	Blue	Khaki	White	Blue
4	Purple	Red	Khaki	Black
5	Khaki	Blue	Charcoal	Pink
6	Pink	Orange	Pink	Yellow
7	Charcoal	Charcoal	Purple	Purple
8	Black	Purple	Black	Orange
9	Orange	Black	Orange	White
10	Red	Pink	Red	Maroon
11	Maroon	Maroon	Maroon	Red

Table 6.7 Comparing the Direct Program Ranking Results among the Stakeholders (2)

Direct Color Rank - Comparing Perspectives				
	Carriers-Carriers	Advocates-Carriers	Policy Makers-Carriers	Shippers-Carriers
1	Yellow	Charcoal	Charcoal	Charcoal
2	Blue	Khaki	Blue	Khaki
3	White	Blue	Khaki	Blue
4	Khaki	Black	Yellow	Black
5	Charcoal	Yellow	Pink	Pink
6	Pink	Pink	White	Yellow
7	Purple	Orange	Black	Purple
8	Black	White	Orange	Orange
9	Orange	Purple	Purple	White
10	Red	Maroon	Red	Maroon
11	Maroon	Red	Maroon	Red

Table 6.8 Description of the Programs selected as the Top Three Options when the Stakeholders ranked from their Own Perspective

Top Three Program Options			
Card Color	Yellow	Blue	White
Percent Reduction	90%	90%	90%
Fixed Cost	\$100,000	\$0.00	\$300,000
Annual Cost	\$75,000	\$50,000	\$50,000
Time to Adopt	Immediate	Next yard visit	Immediate
Service Effects	None	Revision to current logistics	None
Verifiability	Monitored Certification	Calculated certification	Calculated Certification
Reduces other Emissions	Yes	No	Yes

When comparing the results from the attribute orderings, it appears that the groups have a fairly solid understanding of what features other participants consider to be important with regards to emission reduction programs. However, when analyzing the results of the program rankings, the stakeholders did not rank options in an order that aligned with the group whose perspective they were attempting to emulate. For three out of the four groups (Shippers, Advocates, and Policy-makers), their program orders (when assuming an alternate perspective) are significantly different than the actual ranking provided by the category that they are attempting to simulate – the Carriers. To me, this indicated that, although the groups demonstrate a solid and correct understanding of which program features or attributes are most and least important to their fellow industry partners, they do not accurately comprehend how those attribute values translate into program preferences. For example, fixed costs are important to Carriers but that does not equate to a complete aversion to programs that require them.

Also interesting to note is the high level of perceived confidence that the same three groups (the Advocates, Policy-makers, and Shippers) have for the type of program that the Carriers would select as first, as can be seen in Table 6.9 below. These stakeholders, through these stated percentages, demonstrate that they feel certain that the order that they have selected for the alternate viewpoint is right, but they are actually incorrect in their assessment. The Carriers, on the other hand, are less confident in their choices but are, in fact, much more accurate in their alternate perspective program rankings.

Table 6.9 Within-group Consistency Check - Participants' Estimation of Agreement for the First and Last Program Choices when assuming an Alternate Perspective

	Would agree with first card	Would agree with last card
Carriers-Shippers	57%	51%
Advocates-Carriers	70%	77%
Policy Makers-Carriers	67%	61%
Shippers-Carriers	65%	65%

From a policy perspective, these results identify an important area of opportunity. Based on their interactions with and operational understanding of fellow industry participants, these four groups have each formed opinions regarding what is or is not important to the other. In general, these judgments are fairly accurate, as reflected by the attribute rankings in Tables 6.4 and 6.5. However, the participants are incorrect in their assessment of how those views then translate into program preferences. For example, three of the groups (Shippers, Advocates, and Policy-makers) revealed through their rankings (Tables 6.6 and 6.7) that they perceived Fixed Cost, a feature that they thought was most important to the Carriers, was a veritable program deal-breaker. The Carriers, on the other hand, showed through their rankings that this was not actually the case.

In taking the stakeholders through the ranking exercise, this tool was able to identify this misunderstanding. The presence of misperceptions between industry members could negatively impact future policy-making efforts for this issue in several ways. It could, for instance, prevent the consideration of certain programs or the formation of different partnerships. Program options similar to that which occupied the most valued end of the preference spectrum might be ignored or avoided as unfeasible when, in actuality, it is the best suited to meet the objectives of all of the participant categories [28-31, 109, 198].

With an understanding of stakeholder preferences established, the next sections will engage in a more detailed examination of the indirect or inferred exercise results (multiple linear regression), tool design (R^2 (R-squared) estimates), and statistical significance findings.

6.5 Multiple Linear Regression Results

The general goals for the exercise were to improve current levels of information and data regarding key stakeholders' preferences towards emission reduction programs and the attributes that compromise those initiatives by creating a means for providing a snapshot of how those values are impacted in a decision-making or ranking situation. The findings communicated in the previous sections of this chapter suggest that the preference ranking tool can provide insight for those objectives, but in order to test the validity of and results from this technique, the structure and performance of the tool must be inspected through statistical testing. Assessing the design of this style of exercise is accomplished through techniques geared at assuring the statistical significance of the estimated parameters and at confirming the goodness of fit of the model. For this work, the topic of fit was addressed through R^2 (R-squared) estimates, while statistical significance and respondent preferences were managed through an f-test for the exercise as a whole, as well as t-tests and P-value assessments for each of the individual parameters [250, 255-258, 260].

6.5.1 Analysis for Goodness of Fit

To assess the effectiveness of the model for determining the connections between the dependent and independent variables, the first step was to analyze the goodness of fit through the coefficient of determination (or R^2). R^2 serves as an indicator of how well the regression equation explains or defines the relationship among the dependent and independent variables. This analysis allows the researcher to identify the amount of variability in y (the response or rank) that is accounted for by the model with the aim of having a majority of the variability explained [256-258, 261]. R^2 is calculated from the LINEST statistics by dividing the regression sum of squares by the total sum of squares and typically produces a value between 0 and 1. The closer that R^2 gets to 1, the stronger the relationship between the independent and dependent variables (an R^2 quantity equal or greater than 0.7 is recognized as showing a significant correlation between x and y, while R^2 equal to 1 indicates perfect predictability). Conversely, a model with no predictive capability would reveal R^2 equal to 0 [255-260].

Forming a complete picture of how well the model works with the dependent and independent variables necessitated that I analyze both the individual and the group estimates. The individual values would establish if the ranking tool is able to identify and characterize a relationship between the attributes and the program orders and also verify that the participants understood the exercise. The R^2 numbers for the groups, on the other hand, would uncover the level of variability within each of the different stakeholder categories. This step confirms collectively if the ranking tool can gauge the connections between the attributes and the program orders. If there is a fair amount of inconsistency in the rankings within each of the four groups, it would be expected that the R^2 values would be lower (closer to 0). If, however, each category has a notable amount of internal agreement with how the cards were ranked, the R^2 estimates would reflect this with a figure closer to 1 [246, 255-260]. Below, Tables 7.0 and 7.1 exhibit the R^2 values for the individual responses, as well as the group results – first from their own perspective, then followed by the alternate viewpoint. Table 7.2 provides the average pairwise rank correlation for the same groupings. The section after the Tables will further discuss these findings.

Table 6.10 Individual and Collective Group Results for R^2 Analysis (From Stakeholders' Own Perspective)

Carriers as Carriers		Advocates as Advocates		Policy Makers as Policy Makers		Shippers as Shippers	
Participant	R^2	Participant	R^2	Participant	R^2	Participant	R^2
C1	0.99	E1	1.00	P1	0.99	S1	0.97
C2	0.97	E2	0.98	P2	0.99	S2	0.99
C3	0.96	E3	1.00	P3	1.00	S3	0.97
C4	0.94	E4	0.97	P4	0.99	S4	0.81
C5	0.96	E5	0.97	P5	0.99	S5	1.00
C6	0.98	E6	1.00	P6	0.98	S6	0.91
C7	0.87	E7	0.96	P7	0.98	S7	0.84
C8	0.83	E8	0.94	P8	1.00	S8	0.99
C9	0.95	E9	1.00	P9	0.97	S9	0.93
C10	0.97	E10	0.92	P10	1.00	S10	0.95
C11	1.00	E11	1.00	P11	0.97	S11	0.92
C12	0.98	E12	1.00	P12	0.83	S12	0.92
C13	0.94	E13	0.97	P13	0.99		
C14	0.99			P14	0.99		
C15	0.99			P15	0.99		
C16	0.99			P16	0.99		
C17	0.76			P17	0.97		
C18	0.98			P18	0.99		
C19	0.99						
C20	0.92						
C21	0.96						
C22	0.99				Collective Group Results		
C23	0.98				Participant Groups	R^2	
C25	0.91				All Carriers	0.38	
C26	1.00				All Advocates	0.71	
C27	0.96				All Policy Makers	0.68	
C28	1.00				All Shippers	0.43	
C29	0.97						

Table 6.11 Individual and Collective Group Results for R^2 Analysis (Stakeholders Assuming an Alternate Perspective)

Carriers as Shippers		Advocates as Carriers		Policy Makers as Carriers		Shippers as Carriers	
Participant	R^2	Participant	R^2	Participant	R^2	Participant	R^2
C1	0.99	E1	0.96	P1	0.99	S1	0.95
C2	0.97	E2	0.97	P2	0.99	S2	0.99
C3	0.99	E3	0.99	P3	0.99	S3	1.00
C4	0.40	E4	1.00	P4	0.94	S4	1.00
C5	0.97	E5	0.83	P5	0.99	S5	0.99
C6	0.99	E6	0.99	P6	0.98	S6	0.98
C7	0.97	E7	1.00	P7	1.00	S7	0.84
C8	0.93	E8	0.96	P8	1.00	S8	0.68
C9	0.96	E9	0.99	P9	1.00	S9	0.93
C10	0.97	E10	0.96	P10	0.89	S10	0.97
C11	0.87	E11	0.93	P11	1.00	S11	0.96
C12	1.00	E12	1.00	P12	0.97	S12	0.96
C13	0.99	E13	0.90	P13	1.00		
C14	0.97			P14	0.99		
C15	1.00			P15	0.96		
C16	0.99			P16	0.98		
C17	0.96			P17	0.92		
C18	0.99			P18	0.99		
C19	1.00						
C20	0.89						
C21	0.96						
C22	1.00				Collective Group Results		
C23	0.99				Participant Groups	R^2	
C25	0.86				All Carriers	0.37	
C26	0.99				All Advocates	0.55	
C27	1.00				All Policy Makers	0.35	
C28	0.92				All Shippers	0.39	
C29	0.97						

Table 6.12 Correlation Assessment for Each Stakeholder - (Both Perspectives)

Average Pairwise Rank Correlation Analysis							
Carrier-Carrier	Carrier-Shipper	Advocate-Advocate	Advocate-Carrier	Policy-Maker-Policy-Maker	Policy-Maker-Carrier	Shipper-Shipper	Shipper-Carrier
0.3	0.3	0.7	0.5	0.7	0.3	0.4	0.3

6.5.1.1 Discussion of R^2 Results

When ranking from their own perspective (Table 7.0), individual participants had R^2 values that surpassed 0.7, with a majority of the estimates nearing or equaling 1. This same result was largely repeated when ranking the programs from the alternate perspective with only a few responses returning R^2 numbers less than 0.7. These findings validate that the model's design is adequate for assessing the connections between the dependent and independent variables and also support the idea that the participants clearly understood the exercise [241, 255-258, 260, 261]. In each case, the strong individual R^2 values reflect that a majority of the variability in y could be explained through the model with very little unexplained or unaccounted variability noise [257, 258].

The compiled R^2 values for the four stakeholder groups, however, reveal a different result than those for the individuals. Two of the groups, the Advocates and the Policy-makers, maintained R^2 estimates signaling significant relationships (0.71 and 0.68) when sorting from their own perspective, while the Carriers and the Shippers produced R^2 numbers indicating a greater amount of unaccounted variability noise (0.38 and 0.43). These results demonstrate that the Carriers and Shippers are more divergent than the Advocates and Policy-makers in how their attribute preferences affect their rankings with regards to vessel emission reduction programs. For these groups, the model is not able to be as effective at determining clear within-group associations because there is less overall confidence in cumulative program and attribute preferences [255-259].

Carriers and Shippers represent a diverse array of companies with varying sensitivities to potential change. These organizations can vary notably in size and structure, much more so than the Advocates and the Policy-makers, and would also realize the greatest direct impact to their daily operations from any program implementation - with the most significant effects likely falling to the Carriers. Bearing these points in mind, discovering unevenness in the combined rankings for voluntary programs for these two groups is not unrealistic but does, as will be discussed in the final chapter, signal another area of opportunity for future work with the exercise.

When assuming the alternate perspective (Table 7.1), the outcomes for the R^2 estimates also showed variability, with all of the organizations producing lower values (Carriers as Shippers 0.37, Advocates as Carriers 0.55, Policy-Makers as Carriers 0.35, and Shippers as Carriers 0.39). This finding was not surprising. The results from the direct rankings discussed earlier revealed that the groups were less accurate at matching another stakeholder's view or preferences when sorting the programs. Therefore, the fact that each of the groups was unable to produce consistent within-group program rankings for the alternate viewpoint was not alarming.

In looking at the data in totality, the individual R^2 estimates for all of the respondents and the combined R^2 numbers for the Advocates and the Policy-makers indicate that the regression equation could explain the relationship among the variables and defines a strong connection between the attributes and the program ranks. Were this not the case, it would be reasonable to assume that there is a flaw in the design of the exercise and that it is necessary to go back and revise the tool's construction [256-258, 260]. The lower R^2 values uncovered here occurred in situations where previous analysis had already revealed a lack of consistency (stakeholders performing program rankings while assuming an alternate perspective) and with two stakeholder groups at the cumulative level whose individual results had produced significant R^2 estimates. The most unexpected outcomes from the R^2 analysis, overall, were the estimates from the Carriers. This group was perceived within the industry as having assertive and straightforward views on the vessel emissions issue, but, in the exercise, they actually displayed significant variability both from their own, as well as from the alternate viewpoint.

The results and observations detailed above support the idea that the lower R^2 values were caused by a lack of uniformity among the participants and not by an exercise design error. As a means of testing this hypothesis, I created correlation tables for each of the stakeholder groups' cumulative responses. Correlations represent a unit-free measure of the strength of the linear relationship between x (or x's) and y (again, with values approaching 1 proving strong connections). The outcomes from this step, thus, could be used to verify or refute the above proposition that the depressed R^2 values were most likely a result of poor within-group consistency [257-259]. Table 7.2 above presents the results of this assessment. The correlation estimates are, in fact, similar to the above R^2 values, supporting the theory of low within-group uniformity as the cause for the inconsistent program rankings.

6.5.2 Analysis for Statistical Significance

Having completed the assessment for model design, the next step was to move on to tests for statistical significance. For this research, F-test, P-values, and t-tests were used to examine statistical significance. The first of these analyses, the F-value, is obtained by dividing the Model Mean Square by the Error Mean Square (or the MSR by MSE) and is used to establish whether or not the model as a whole has a "statistically significant predictive capability" [255-258, 261]. The second of these analyses, P-values are used to determine whether a variable has "statistically significant predictive capability in the presence of the other variables" – whether it adds something to the equation, and the third analysis, the t-test, reveals how statistically significant each attribute is to the various stakeholders collectively in determining the rank of the card or program – the "ratio of the sample regression coefficient to its standard error" [255, 257, 258]. Tables 7.3 through 7.5 below present the results for the F-test and P-values. Figures 6.0 – 6.6, which present the results for the t-tests, will appear in the t-test section, following the analysis for the F-test and P-values.

Table 6.13 Collective F-values Estimated for Each Stakeholder and Perspective

F-observed Values for the Stakeholders							
Carriers-Carriers	Carriers-Shippers	Advocates-Advocates	Advocates-Carriers	Policy-Maker-Policy-Maker	Policy-Maker-Carrier	Shipper-Shipper	Shipper-Carrier
19.96	24.59	48.23	23.75	58.8	14.88	13.18	11.35

(All estimates surpass the necessary F-critical values)

Table 6.14 P-value Results Denoting Inferred Attribute Importance (Stakeholders from their own Perspective)

	Carriers-Carriers	Advocates-Advocates	Policy-makers-Policy-makers	Shippers-Shippers
Variables	Significant P-Values			
Percent Reduction	7.41×10^{-9}	1.39×10^{-21}	6.47×10^{-27}	0.00014
Fixed Cost	0.038		0.013	
Annual Cost				
Time to Adopt		0.031	0.0049	0.094
Service Effects	0.027			0.05
Verifiability			0.099	
Reduces Other Emissions		0.0087	0.033	0.10

(Underlined values represent marginally important variables (P-values < 0.10 and > 0.05))

Table 6.15 P-value Results Denoting Inferred Attribute Importance (Stakeholders from the Alternate Perspective)

	Carriers-Shipper	Advocates-Carriers	Policy Makers-Carriers	Shippers-Carriers
Variables	Significant P-Values			
Percent Reduction	5.06×10^{-12}		0.009	
Fixed Cost	0.006	0.0008	0.03	
Annual Cost	0.10	0.02	0.06	
Time to Adopt	0.09			
Service Effects		0.03	0.04	
Verifiability				
Reduces Other Emissions				

(Underlined values represent marginally important variables (P-values < 0.10 and > 0.05))

6.5.2.1 The F-test

In consulting other regression analyses and statistical texts, I found evidence that an F-value greater than 6 denotes that the model in question does have significant predictive capabilities [256-259]. Based on the parameters of this tool's design, assuming a single-tailed test, an Alpha value of 0.05 and 3 degrees of freedom, the F-critical values for this exercise would be 5.27 for a 90% confidence level and 8.89 for a 95% confidence level. Therefore, if the F-observed statistics shown above in Table 7.3 are greater than these F-critical values, then the model demonstrates a significant relationship between the dependent and independent variables [256-259].

Across all of the four categories, the collective F-observed values were consistently greater than the F-critical values. Thus, the coefficients and intercept estimates calculated through this regression work and presented in the LINEST arrays could be used to analyze how preferences for different initiatives change (for each of the groups) as the variables representing the attributes vary [255-259].

6.5.2.2 P-values and T-tests

As was mentioned above, the P-values are used to determine whether a variable has "statistically significant predictive capability in the presence of the other variables" – whether it adds something to the equation, and the t-test reveals how statistically significant each attribute is to the various stakeholders collectively in determining the rank of the card or program – the "ratio of the sample regression coefficient to its standard error" [255, 257, 258]. The results from these examinations verify whether or not the selection of attributes was appropriate for this problem with these sample groups, and also provides further insight into what exactly is important to whom by highlighting which attributes of programs different stakeholder groups value most and least (based on how the cards are ranked). These inferred results can then be compared to the direct ranking responses to ascertain how the two compare [256-259].

6.5.2.2.1 Results for the P-values

Because the LINEST function does not provide P-values in its results, I used Excel's Regression option to determine these estimates. This step produced a few additional regression statistics and served as a way for me to verify the cumulative LINEST results [259]. The P-values also have approved standard limits for determining significance. If the P-value is less than 0.05, then the variable is said to have a statistically significant predictive capability. P-values falling between 0.05 and 0.10 are classified as occupying a marginal level of importance. They are identified as important additions to the equation, confirming that they should be included in the exercise, but with the understanding that these factors are not as decisive in predicting participant ranks [255-259]. Tables 7.4 and 7.5 above present the stakeholders' significant (and marginally important) P-values for each of the seven attributes based on how the programs were ranked, first from their own perspective and then from the alternate viewpoint.

Based on the cumulative responses for each of the stakeholders when ranking the programs from their own perspective, six of the seven attributes displayed significant P-values, with percent reduction serving as the most critical component for each of the groups. The remaining attributes were highlighted separately by different stakeholders and aligned well with acknowledged concerns and objectives for each category.

The fixed costs and service effects are decisive elements for Carriers, while time to adopt and reducing other emissions are key factors for the Advocates. Policy-makers share the desire for additional emission reductions and timely implementation, but the costs, as well as how the programs will be maintained (verifiability), are also crucial factors to them. Finally, the Shippers show that possible impacts to service are important to their preferences, with time and the ability to reduce other emissions also weighing in. Compared to the direct ranking results shown in the first sections of this chapter, these inferred values produce a more well-rounded picture of the groups' attribute preferences. Because these P-values are calculated based on how each of the stakeholders ranked the cards, these results offer a different view of the motivating factors for each stakeholder by exposing how a decision-making or trade-off situation influences attribute importance [255-259].

The results from the alternate perspective reinforce the findings from each of the previous analyses from the different viewpoint. The stakeholders have general perceptions of other participants' program and attribute preferences but are not necessarily confident, consistent, or accurate in these views. On one end of the spectrum, the Policy-makers provide the best match to actual Carrier preferences. The Advocates occupy a middle ground with a somewhat accurate comprehension, while the Carriers and the Shippers are at the least consistent end, with the Shippers unable to produce any significant P-values through their collective program rankings.

The incorporation of the Shipper viewpoint is new from a policy perspective, and, within the Shipper category, the vessel emissions issue is still a relatively new topic for these companies. They have not, either independently or through invitations from other industry partners, been as actively involved in work or forums on the topic so, up to this point, their views are not yet as well debated as the others. I believe that their collective inexperience is what led to the lack of affinity and confidence in their P-value results compared to the other stakeholders.

Each of these stakeholders is progressively feeling increasing pressure to support and implement activities for ongoing environmental improvements. For the vessel emissions issues, without consistent, multi-participant acceptance of proposed solutions, achieving significant improvements will be much more difficult. Therefore, utilizing methods such as this to improve these stakeholders' abilities to identify and understand industry preferences and objectives is important. This type of tool represents one option for achieving this goal, and it has proved to be both adaptive in its design and effective at providing insight [29, 31, 231, 234].

The P-values determine whether a variable has a statistically significant predictive capability (or, in this case, a very strong preference) in the presence of the other variables. Understanding which attributes different stakeholders reveal as being the most critical to how they assess environmental programs can help a researcher to identify whether or not an appropriate mix of attributes is being pursued and to formulate program options that are based on valid and accurate information on motivating factors [255-259].

The above tables show that each of the seven attributes was recognized by at least one of the stakeholder categories with a significant P-value, signaling that the mix of attributes was appropriate for the sample population and the problem. However, annual costs were only identified as significant by participants when ranking from an alternate perspective, not when the respondents sorted as themselves. The data from the alternate perspective has been shown to be notably less precise and consistent than the straightforward orderings so, prior to any future work with the exercise, the annual costs attribute should be revisited with the stakeholders to consider the possible omission or revision of this element [257, 258].

6.5.2.2.2 Results for the T-tests

The P-values establish which program components are the most important to each stakeholder based on how the cards were ranked. The t-test, the last assessment for statistical significance, is also used to determine the significance of the seven attributes, but, for this work, I am employing it as a means for recognizing the strength of the attribute preferences within each of the participant categories. Performing this task required that I first determine the t-statistic and then compare the t-statistic to the t-critical value. The coefficient and standard error estimates needed to calculate the t-statistics for each of the responses were provided by the LINEST array, while the t-critical value was determined through a t-distribution table – considering the population's degrees of freedom and a 90% confidence level. A positive t-test (where the t-statistic is greater than the t-critical value) would signal that the particular attribute had a noteworthy impact on the ranking [257, 258, 260].

The necessary data was calculated and compiled for each group's own perspective, as well as the alternate viewpoint. The following graphs (Figures 6.0 – 6.5) display the cumulative strength of significance for each of the seven attributes by showing the percentage of the sample populations that revealed a statistically significant t-test for that particular attribute.

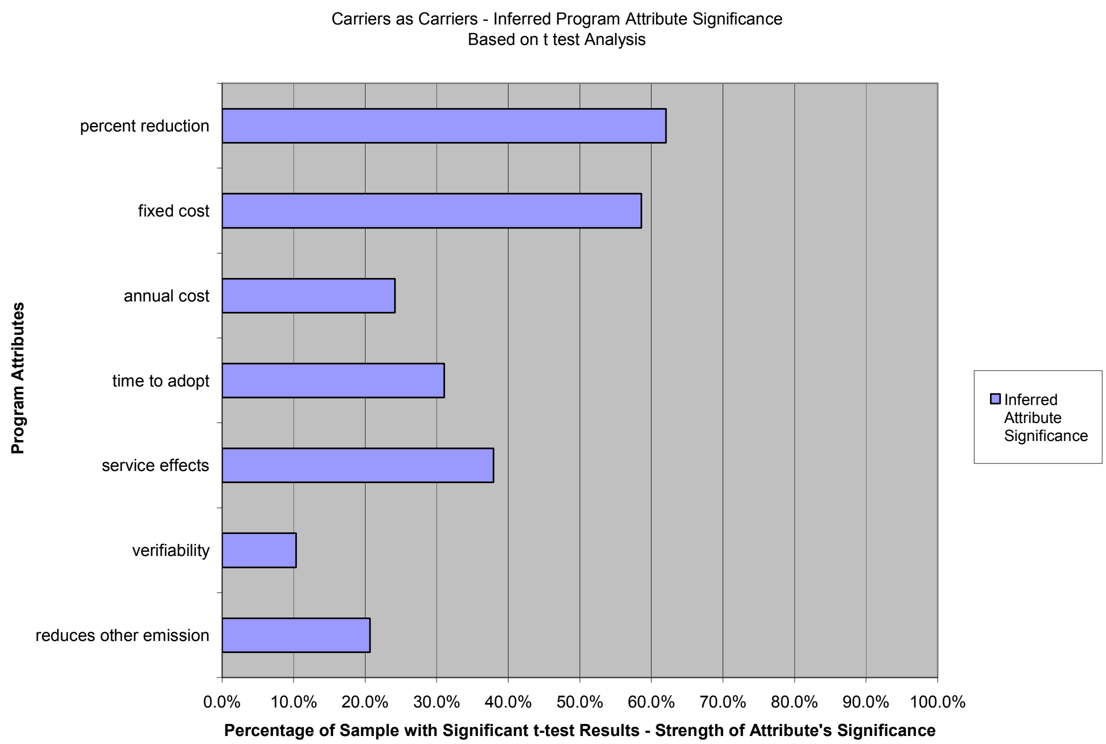


Figure 6.1 Carriers as Carriers – Inferred Program Attribute Significance Based on t test Analysis

The percent reduction and fixed cost attributes had the greatest impact on program selection for the vessel operators. Around 60% (62% for percent reduction and 59% for fixed cost) of the respondent pool registered notable t-test results for these two factors. Service effects, time to adopt, and annual costs were more moderate in their influence with between 25–38% of the population showing them as important influences to the rankings, while reducing other emissions and verifiability elicited the least impact to the group's program preferences.

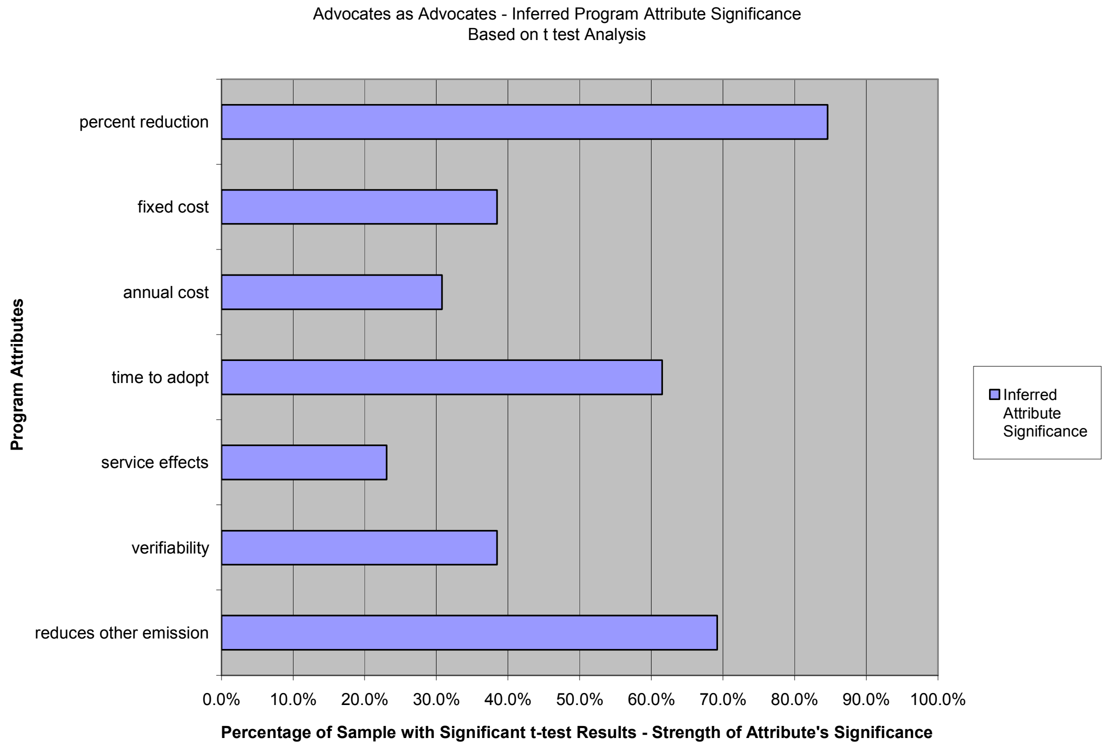


Figure 6.2 Advocates as Advocates – Inferred Program Attribute Significance Based on t test Analysis

The Advocates had very confident and consistent attribute preferences. Percent reduction, reducing other emissions, and time to adopt were statistically the three most significant attributes for this category with 85%, 69%, and 62% of the sample showing that greater reductions (both in amount and type) and faster implementation are, to them, the most pivotal attributes to overall program preference.

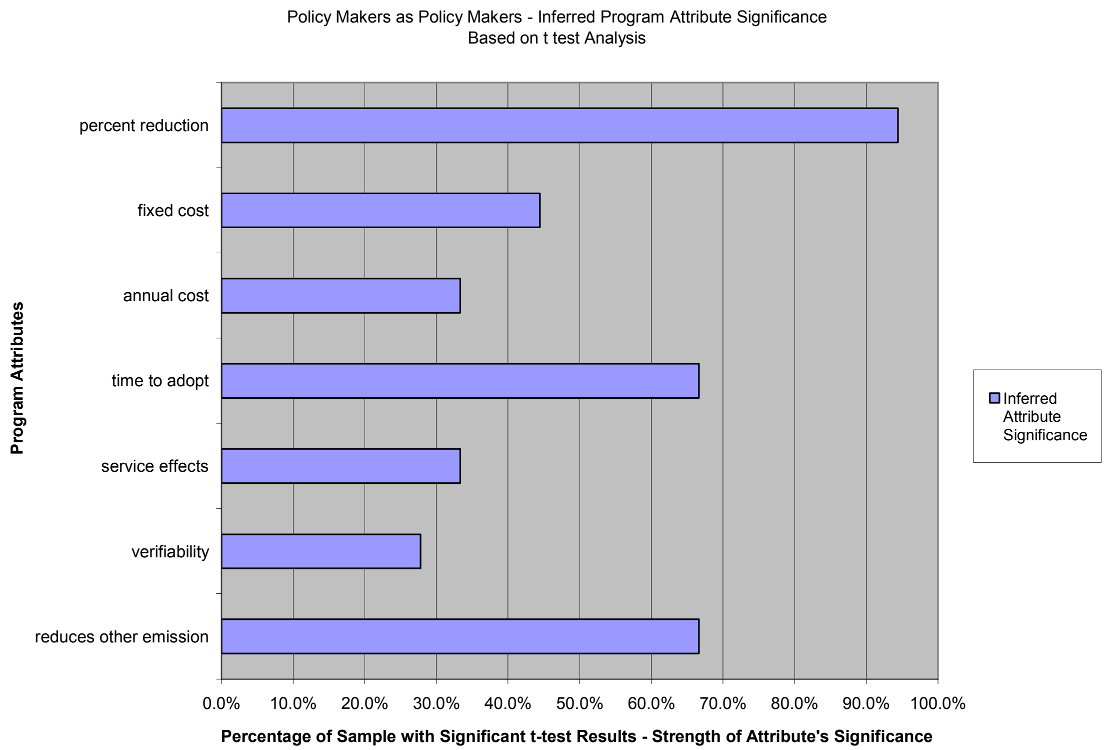


Figure 6.3 Policy-makers as Policy-makers – Inferred Program Attribute Significance Based on t test Analysis

Participants within the Policy-maker group selected percent reduction, reducing other emissions, and time to adopt as the most prominent of the seven attributes, similarly to the Advocates. 94% of the sample population found percent reduction to be decisive in which programs were considered favorable, with around 67% supporting time to adopt and reducing other emissions. Fixed costs were of moderate importance to the policy-makers (44%), while annual costs (33%), service effects (33%), and verifiability (28%) proved to be least critical to the overall rankings

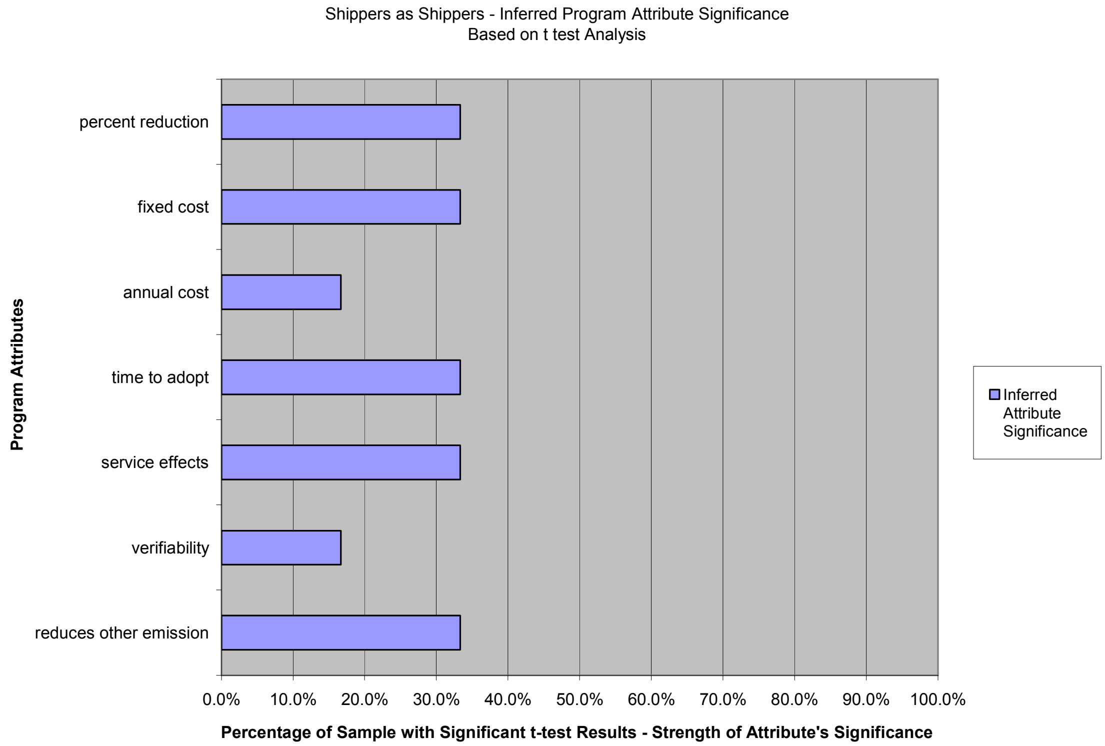


Figure 6.4 Shippers as Shippers – Inferred Program Attribute Significance Based on t test Analysis

The Shippers produced results that were much less decisive or assertive when judged against the other stakeholders, but, nonetheless, these outcomes do appear to realistically represent their objectives. Percent reduction, fixed cost, service effects, reducing other emissions, and time to adopt emerged as the most critical factors to these participants, with around 33% of the sample identifying each of these elements as being notable to how the programs were ranked. The lack of confidence (or strength) in these findings could be attributed to several factors. Again, based on my encounters with this group, I would accredit it to their lack of experience with the issue as compared to the other stakeholders.

Although the Shippers are considered vital members of the international shipping community, their participation in the major debates, forums, or discussions for this problem has been limited. The companies who are pursuing some kind of activity on the topic, such as those involved in this exercise, are doing so voluntarily through small, specialized groups or through unique business or program opportunities [205]. This stakeholder category offers a rich assortment of resources and a history of innovative thinking that could be incredibly valuable to the vessel emissions topic. If, as this research encourages, Shippers were progressively incorporated into the vessel emissions debate, their preferences would likely change to reflect their growing knowledge and experiences.

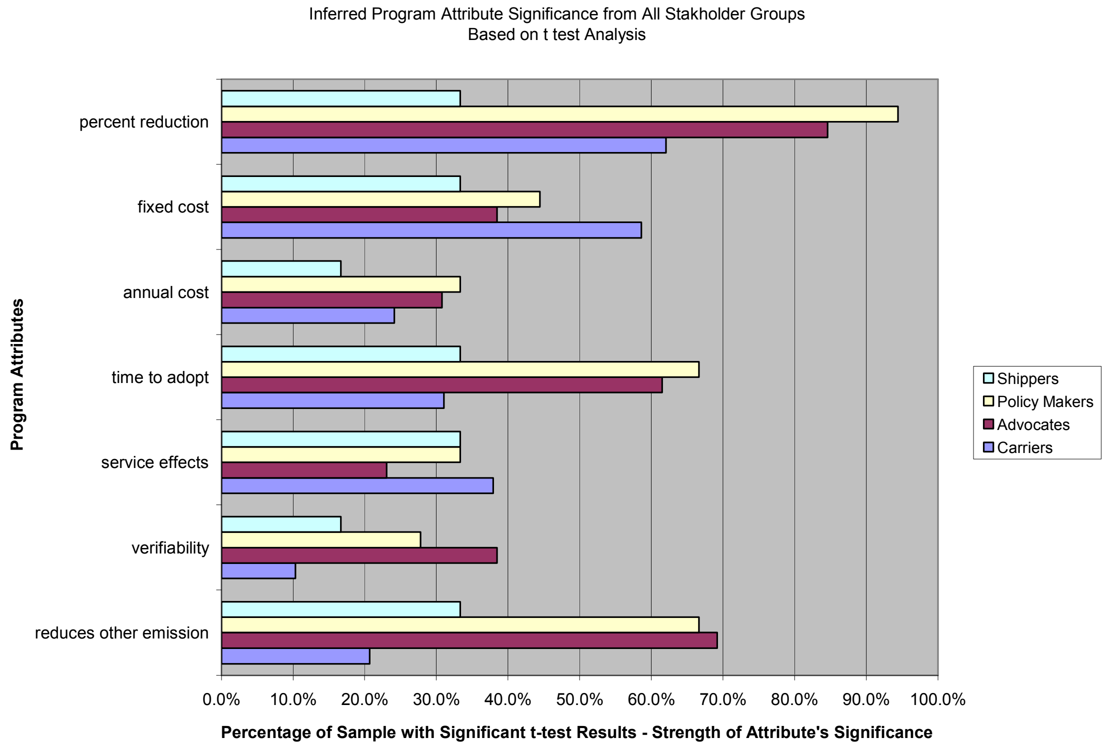


Figure 6.5 Inferred Program Attribute Significance from All Stakeholder Groups Based on t- test Analysis

Viewing the stakeholders' collective t-test results (Figure 6.4) simultaneously provides an understanding of not only which attributes are important to which groups but also a feeling for the magnitude of their preferences. As changes are proposed to various program components or occur within stakeholder perspectives, this test provides a mechanism for gauging or predicting participant responses. It also helps to judge the effectiveness of the mix of attributes. If the strength of significance for a particular characteristic fades or grows, the researcher can revisit the topic with the respondents and adjust the tool (and potential program) accordingly. Exercises such as this, which have been developed to aid in complex decision-making situations, are often praised for their ability to inform, but their capacity to establish structure and to serve as a chronicle of data over time also makes them invaluable assets for policy-focused research.

The results for the stakeholders (when ranking from their own perspective) offer insight into one dimension of the vessel emissions issue. The decision to include an additional ranking, assuming an alternate perspective, provided visibility into perceptions that are present within the different stakeholder groups. The graphics below (Figures 6.5 and 6.6) present the t-test information gathered from the alternate perspective.

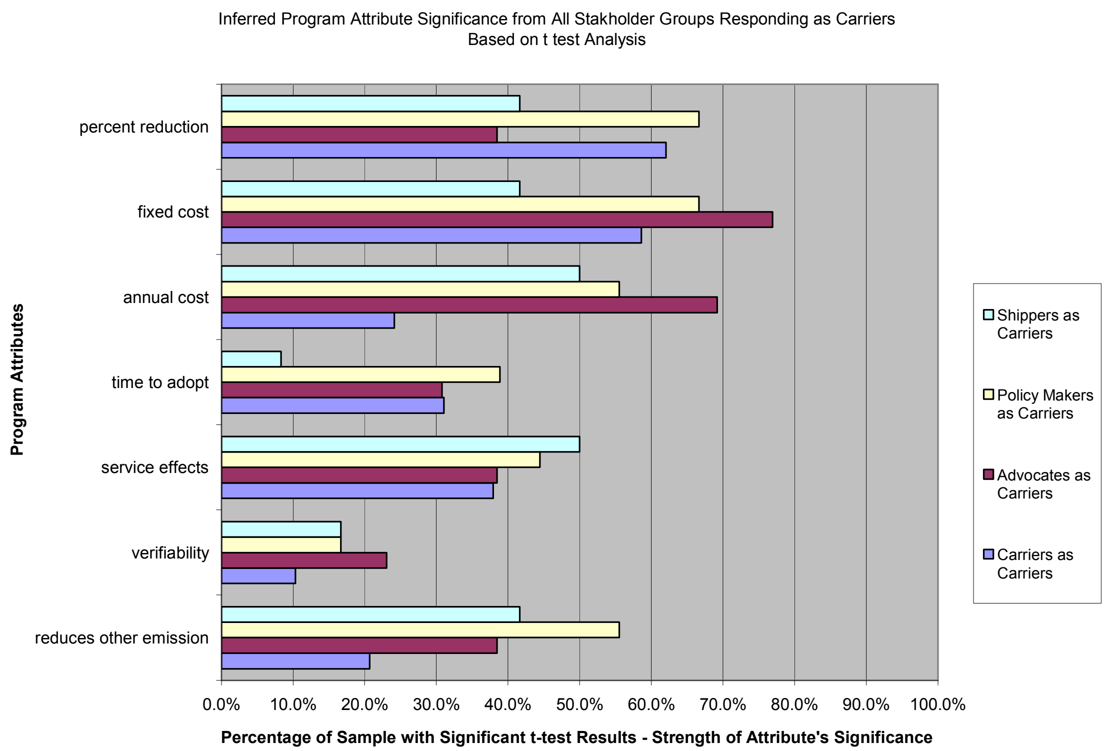


Figure 6.6 Inferred Program Attribute Significance from all Stakeholder Groups Responding as Carriers Based on t test Analysis

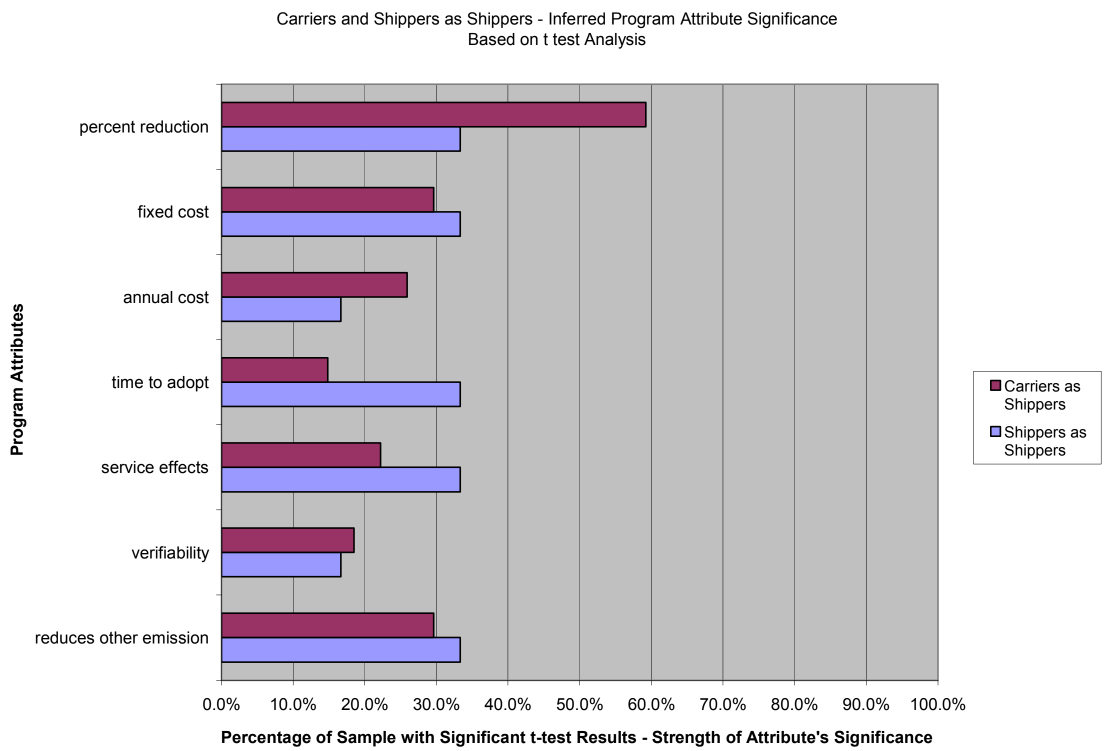


Figure 6.7 Carriers and Shippers as Shippers – Inferred Program Attribute Significance Based on t test Analysis

Insights or results gathered from the alternate perspective could be used to identify and monitor areas where misperceptions or invalid opinions could be preventing or harming forward progress or where solid inter-group awareness could signal the potential for meaningful partnerships with more predictable outcomes. When asked to think like a Carrier, the other stakeholders were unable to effectively or consistently match actual Carrier preferences. They each were aware of the importance of possible operational impacts to the vessel operators (costs and service effects) but were largely incorrect on the value of environmental features, such as percent reduction. When Carriers were asked to rank as Shippers, their opinions were more in line with actual Shipper preferences but there were also recognizable areas of divergence.

Going into this work, I did not expect that the different stakeholders would be able to match each other's preferences with complete accuracy. Rather, the goals were to expose how well the participants comprehend other industry views on the vessel emissions issue and to force them to look at the problem from a different perspective. Both of these objectives, I believe, the exercise achieves successfully. Ongoing work aimed at ameliorating emission impacts, either in the form of voluntary initiatives or mandatory regulation, will require collective commitments and actions from all of these industry participants to facilitate change. Determining ways to improve inter-stakeholder awareness and communication, therefore, would aid in the process of establishing effective and well-accepted solutions, ideally in a timelier manner [28, 29, 33, 235, 242].

6.6 Summary

Misperceptions and other communication blocks can be destructive or prohibitive to the policy-making process. Therefore, discovering a means for defusing these tendencies – the "we vs. them" mentality - can be pivotal to establishing significant forward movement on any given issue [28-31, 235, 237]. Each of the four stakeholder groups analyzed here is driven by a specific set of objectives and every alternative for reducing vessel emissions has the capability of impacting those goals in a number of different ways. Prior to my running this exercise, neither I nor my participants would have predicted that the groups would agree on their top program of preference. However, that is exactly what happened, and, once that finding surfaced, the dynamic of the discussions with and among the respondents changed. The ability to identify areas of concurrence is recognized as an asset when dealing with organizations representing alternative views on a contentious topic, as it provides a starting point for discussion, facilitating negotiation, and building trust [28, 31, 33, 198, 242, 254]. This thesis research also found this to be the case. Undoubtedly, the discovery of discrepancies (in what have evolved into very entrenched views and perceptions) alarmed these decision-makers, but it also sparked their interest and made them eager to learn and understand more.

The detailed, multi-layered process used to identify appropriate attributes and to construct realistic hypothetical programs was pursued with the aim of building a tool that could assess both program and attribute preferences for each of the different stakeholders. The above analysis confirms that the design of the exercise is effective for attaining these goals. By providing a clear, structured, and reproducible means for identifying both the effects and the evolution of the environmental, economic, and operational preferences of the affected parties, this tool provides information that is valuable to future policy development - regardless of type (regulation, covenant, communication, etc.) or level (international, national, or industry-based) [30, 33, 198, 235, 242, 254].

Chapter 7

CONCLUDING OBSERVATIONS

7.1 Introduction

The overarching goals of this research were - to identify, demonstrate, and begin to build a better understanding of the interconnections between policy-making, technology, and stakeholder preferences, and to make a case for more detailed analysis regarding the approaches and methods being utilized by MTS decision-makers within the current environmental policy-making framework to assess how and where improvements could be made. This chapter sets forth the lessons learned as well as some final supplemental observations from this research. Additionally, it will discuss the implications of this work for the current environmental policy-making framework and offer suggestions for future study.

7.2 Supplementary Research Observations

Chapter 6 presents the results from the preference ranking exercise. However, during the process of running the exercise and collecting that data, I also encountered some additional qualitative and design elements. As they help to round out the experience that I had with the preference ranking exercise, I felt that these points should be included.

The first comment relates to the reaction that I witnessed from the stakeholders towards the design of the exercise. Prior to the first execution of the tool, there was discussion about the possibility of eliminating some of the attributes to reduce the overall number of cards for ranking. Respondents, however, confirmed the importance of each of the attributes and gave no comments or indications, even when directly questioned about the number of cards, that the series of 11 was overly burdensome or that the ranking task was too complicated. In fact, many remarked on how selecting from only a few choices would have made the technique seem less realistic, as more often than not there are numerous options available for consideration.

Perhaps, if I had gathered information from a larger sample of maritime professionals, regardless of their knowledge of the vessel emissions topic, having fewer attributes and, thus, card choices would have been better. But, I felt that focusing on those who were well versed on the topic would allow for a more detailed and realistic assessment of what policy features actually matter most to the individuals at the forefront of this problem for these different organizations. The choice to pursue this more specialized sample, however, also meant that my total sample size for each of the groups was kept small. Although arguments could be made for the potential risks to the statistical analyses from selecting this course, in this case, the most meaningful results would be obtained from those who work closely with the vessel emissions issue (they would be the ones responsible for making the decisions for this topic within their own group). As was discussed in Chapter 5, this approach is recognized and supported by decision theory work and studies [28-31].

Overall, the stakeholders clearly understood the purpose and process for completing the tool, with only two exceptions. In the Carrier category, one individual reversed the ranking (listing the programs from least to most preferred rather than the opposite). This participant's series of answers, therefore, had to be inverted when they were entered into the spreadsheet to match the others. Another Carrier's set of rankings were found to be extremely erratic. His or her selections signaled either that he or she did not understand the exercise or did not take it seriously and served to confound the overall data set. For this reason, this person's rankings were omitted from the sample.

The last observation, which was continuously repeated during the data collection process, deals with the reaction from the respondents towards the use of this type of tool for this kind of problem. The preference ranking exercise consistently and successfully served as a mechanism for initiating productive and insightful conversations among the various stakeholder groups. This result supports the idea that there is value and opportunities for the utilization of decision-making techniques within this international industry. Many of the organizations were aware of these kinds of tools being used in areas such as marketing and new product development, but employing one to facilitate research on environmental issues was a new approach. This preference ranking exercise and other types of decision-aiding techniques would be effective at producing a pro-active and collaborative environment. By providing objectives, guidance, and a process, these types of tools set an expectation for results that allows the participants to focus and also supports forward movement on topics rather than cyclical debates [28, 29, 31, 168, 198, 237].

7.3 Implications of this Research to the Current Policy-Making Process and Environmental Framework

Identifying, measuring, and understanding the impacts of the vessel emission issue is important and has been a critical focus to current. This work proposes, however, that transitioning attention and research now to focus in on the process – on studying ways to specifically improve and expand the environmental policy-making framework – is an effective means for supporting and facilitating continuous improvements in the reduction of vessel emissions. There are a variety of policy tools that are available, and, there are also now several proven techniques or technologies ready for use to reduce vessel emissions. Determining different or innovative ways in which to combine these elements could work to promote more rapid implementation of current options or ongoing efforts to establish new inventions or innovations, both of which would benefit the MTS and the work to reduce vessel emissions over time.

Environmental problems like the vessel emissions issue are not and, thus, should not be treated as single solution problems. Each policy option - environmental standards, economic incentives, subsidies, communication initiatives, and covenants – is designed to appeal to and create changes for different impulses. Proactively pursuing their utilization in complimentary ways creates a means for generating greater potential environmental impacts (the ability to impact the problem from different directions or at different levels), technological impacts, and also serves as a productive means for encouraging and facilitating the involvement of all impacted stakeholder groups [107, 110, 169]. The utilization of different types of techniques has emerged at local levels, such as port communities, out of frustration and intense community pressure for action, but their use at a more industry-wide level has not yet been aggressively pursued [38]. This remains an area of opportunity that policy-makers should actively pursue.

The following are examples of environmental programs – a communication program and covenant - that could be applied at the industry level to promote ongoing emission reductions. Each of these options represents realistic alternatives that are informed by and incorporate key principles from this research.

Organization theory stresses the critical impact that the views and values of a company's leadership – CEO, Board of Directors, VP, etc. – have on how the firm operates. Therefore, the strength of the environmental beliefs and values of the upper management greatly impacts the intensity of the company's environmental commitments and initiatives [110, 262, 263]. This point is supported in the current business world by the evolution of a select but growing group of companies that have become recognized as trailblazers within their industry for their management teams' pursuit and development of environmental programs [262, 263].

A communication program focused on identifying and bringing together a collection of directors – CEO's, Operational Directors, Managers, etc, - from each of the different stakeholder groups – shippers, carriers, policy-makers, ports, and NGO's – could be developed to facilitate information sharing across stakeholders on the vessel emissions issue. Collaboration such as this among a group of environmentally like-minded leaders would be a way to incorporate all groups, including shippers, into the emissions issue. It would also provide a productive means for overcoming some of the weaknesses that were uncovered by the ranking tool, such as misperceptions regarding the types of options that participants consider feasible, while simultaneously building or formulating solutions within a network of those who would then also be the most likely to want to first participate.

Greater involvement from the private sector could help to offset administrative costs while providing additional benefits such as greater access to or support of new technologies and operational practices, as well as more information regarding equipment, operations, or effective business processes [16, 110, 116, 139, 141, 264]. Additionally, these organizations are held accountable for their daily operations by a highly sensitive mix of investors, employees, partners, customers, and outside watchdog organization, and they also are at risk for potentially severe market and profitability penalties if there is damage to their brand image – factors that could serve as an impetus for these organizations to participate in this type of option.

These same characteristics also support the creation of action-oriented environmental goals within corporations (for example, facilitating the recycling of a certain percentage of wastes, incorporating certified green building practices into their locations, seeking membership in business-based environmental organizations, etc.) [175, 176]. This desire for action-oriented solutions helps to make the second proposed option - voluntary participation in a logistics-based environmental initiative (the premise behind the preference ranking exercise) - a more viable option than what was first anticipated.

Proposals for per-TEU environmental charges that could be used for the purchase of emission-reducing technologies have been discussed, but the large number of transactions involved and the likelihood of attempts for alterations during annual freight rate negotiations make this track more problematic. An alternative to this idea that is more feasible would be a jointly-managed (industry/government) fund for the development, acquisition, and maintenance of environmental technologies. Directed and administered by a group of representatives from participating shippers, carriers, agencies, engine or technology manufacturers, and non-governmental organizations, members could contribute agreed annual amounts (which might be based on a per-TEU charge or total annual cargo volume) to be used by or distributed within the participant group to facilitate the development and implementation of abatement techniques based on approved proposals.

This type of set up would represent a transportation network solution to the vessel emissions problem and also supports and aligns well with the technological component of the system. On the one hand, since all of the members would be contributing, the financial and operational burdens would be better distributed. Additionally, because each of the participant groups plays a part, they would all be able to lay claim to the reduction benefits. Finally, from a technology change perspective, this type of initiative could be used to facilitate changes all along the technology pathway. Firms with an innovation focus would benefit through more consistent access not only to funding but also to resources such as ships, information, and technical equipment. Diffusion-minded groups on the other hand would also benefit in that this more conservative, 'partnership' style (rather than a more risk-taking approach) would help to encourage and facilitate a reduction in various "thresholds" that could otherwise prevent these organizations from making additional changes or advances [34, 35, 172, 194].

This discussion serves to illustrate the range of opportunities that emerge when the focus is placed on finding ways in which to effectively align the elements of policy, technology, and stakeholder input, rather than deal with them individually. By utilizing a complimentary mixture of communication, economic incentive, and covenant style methods, it is possible to construct a different approach to the vessel emissions issue. One that has the purpose, technological awareness, leadership and membership capabilities, as well as structural support, and funding that would be necessary to make it an effective, progressive, and sustainable system for developing and implementing abatement solutions.

As of yet, these types of programs have not been actively pursued as truly viable alternatives. However, their flexibility, versatility, and innovative nature are exactly what is needed in the policy-making process for the vessel emissions issue. As was presented in Chapter 2, many of the companies involved in the international container shipping industry have the capability of individually creating notable impacts, meaning that even if an inaugural group of participants would be small in number the impacts from any group action would still be notable. Results, in the form of recognizable reductions in vessel emissions, are what policy-makers have been trying to achieve since the 1990's. But, unless the mindset regarding how those results are achieved can be changed to become more accepting towards new ideas and approaches, it is highly likely that the effects from ongoing policy work will continue to be disjointed, and fraught with intra-industry conflict.

7.4 Future Research

The opportunities that are available to continue and advance work aimed at improving the policy-making process within the realm of international shipping are numerous. This research focused on establishing a strong theoretical and practical foundation in support of a shift away from a singular focus on particular groups or mechanisms and towards the development of an environmental framework that is aware, informed, and responsive to the critical elements impacting policy decisions and solutions (technology, stakeholder preferences, and the type of policy approach) - one that is capable of addressing complex and multi-faceted environmental problems like the vessel emissions issue as an integrated transportation network. Specifically, this work investigated principles and techniques from both technology change policy and decision theory to determine if and how they could add value and insight for decision-makers on environmental issues, and, based on the results discovered stemming from those two areas, there are two paths for additional or ongoing work that I feel would be important.

The first relates to the ongoing study, utilization, and advancement of decision-aiding techniques within the MTS. Decision tools and theories have grown out of extensive research aimed at creating a better understanding of and facilitating a more productive approach towards the development of effective solutions to incredibly complex problems involving multiple, often conflicting objectives [28, 29, 31, 235, 237, 242, 265]. Numerous sectors have recognized the value that is inherent from this kind of work for commercial topics, but the value that they provide can be equally useful for public sector areas, such as environmental policy.

The flexibility and adaptability inherent through conjoint analysis is one of the reasons that it was selected for use in this type of research. Because of these features, this method can continue to be tweaked or refined over time to be able to continue to reveal relevant information while also serving as a timeline or historical reference for the groups involved. Future work with this tool could focus on advancing or further studying some of the discoveries that surfaced during the analysis for this work (presented in Chapter 6). For example, one of the findings from the exercise related to inconsistencies – inconsistencies in stated versus implied preferences, in how stakeholders viewed others' preferences, etc. The preference ranking tool through this research was used as a means for capturing or identifying these critical pieces of information, but it could also be used as a means for addressing these specific issues. For example, with a series of initial findings available, it would be both interesting and meaningful to bring back together a group of participants representing each of the stakeholder groups to go through the exercise again to assess whether or not additional discussion and analysis of the results and the topic itself as a transportation network would be able to adjust or correct any of the initial inconsistencies. In this way, the tool could also be utilized with additional decision-aiding techniques to create or facilitate a more comprehensive, progressive, and multi-layered decision analysis process. Additionally, this same collective of individuals could revisit the attributes and levels to determine if any changes to these elements are deemed necessary and, if so, what those adjustments would reveal.

Prior to my running this exercise, neither I nor any of my participants would have predicted that the groups would agree on their top program of preference. However, that is exactly what happened, and, once that finding surfaced, the dynamic of the discussions with and among the respondents changed. This point is critical. Tools used to dissect, inform, or question the decision-making process are designed to try to identify and understand the key elements that influence a participant's views or choices. Additionally, facilitating them and the discussion of the results that are discovered through them serves as an organized, quantifiable, and non-emotive means for facilitating dialogue on preferences and values across stakeholder groups. Because this kind of work has not been actively pursued within the MTS, additional research aimed at introducing other methods or studying different techniques capable of better acknowledging, informing, understanding, or analyzing stakeholder decisions has the potential to produce new findings and valuable insights.

The second area where additional research would be beneficial relates to the technology component. The vessel emissions problem has evolved into a very technical issue. However, in order to use policy to facilitate ongoing innovation and diffusion of the technologies capable of reducing current impacts, there must be a clear recognition that the choice in mechanism has the ability to create distinct impacts on not only the environment but also the technology path [34]. Currently, there is not a substantial amount of work regarding how policy choices can impact or affect that element or on how specific mechanisms could be used to effectively address or promote certain points along the pathway – invention, innovation, or diffusion. This would be another area in which additional work could benefit the long-term effectiveness of the environmental policy framework within the MTS.

If technologies are viewed as viable solutions to environmental issues, then learning about or discovering ways in which to influence technology processes should become a much more prominent element within policy practice and studies. The containerized shipping unit is not the only sector within the marine transportation system where technology plays a prominent role. Therefore, studies geared to assess this area within any maritime segment will create information that would be useful and applicable to other sectors.

7.5 Concluding Remarks

Containerization, the brainchild of transportation specialists like Mc Clean and Brush, has not only completely transformed the maritime industry, but also the world in which the MTS operates. By decreasing costs and increasing efficiencies, containerized shipping has been able to increase the overall size of the good movement pie, but this expansion, as with all rapid developments, has come with its own set of challenges, including the issue that is the focus of this research – the vessel emissions issue [13-15]. The international container shipping industry and the vessel emissions issue are complex and multi-faceted topics that must have dynamic and comprehensive solutions. Achieving substantial, long-term environmental improvements within this type of system will necessitate additional work focused on better understanding the critical elements that are driving the system.

As the above chapters have shown, within the international marine transportation system, the three areas of critical importance to the vessel emissions issue are technology (and technology change), type of environmental policy mechanism, and stakeholder preferences for emission reductions. Each of these elements influences the problem and the process in a different, yet important way. Therefore, supporting a more assertive and consistent change in the vessel emissions issue could effectively be achieved through a better recognition of the capabilities and effects of these three areas. As with other interconnected industries, both the problems and the processes are becoming increasingly complex within the MTS, a development that is progressively blurring the boundaries between areas such as environmental policy-making and technology policy. In response to this, policy-makers should also begin to adjust their approaches and methods to better recognize and understand these different impacts, as it will be through this type of work that decision-makers will be able to develop the responsive and innovative arsenal of policy tools that is capable of creating significant change.

REFERENCES

1. A.J. Kean, R.F.S., and R.A. Harley,, *A Fuel-Based Assessment of Off-Road Diesel Engine EMissions.* Journal of the Air & Waste Managment Association, 2000. **50**(11): p. 1929-1939.

2. Booz Allen & Hamilton Inc., *Commercial Marine Vessel Contributions to Emission Inventories: Draft Final Report*. 1991, Booz, Allen & Hamilton, Inc.: Los Angeles, CA.

3. Corbett, J.J., *New Directions: Designing Ship Emissions and Impacts Research to Inform Both Science and Policy.* Atmospheric Environment, 2003. **37**: p. 4719-4721.

4. Corbett, J.J. and P. Fischbeck, *Emissions from Ships.* Science, 1997. **278**(5339): p. 823-824.

5. EPA, *Final Regulatory Impact Analysis: Control of Emissions from Compression Ignition Marine Engines*. 1999, U.S. EPA Office of Air and Radiation: Office of Mobile Sources, Engine Programs and Compliance Division: Ann Arbor, MI. p. 132.

6. EPA, *40 CFR Parts 89, 92, and 94: Control of Emissions of Air Pollution from New CI Marine ENgines at or above 37 kW, Final Rule*. 1999, U.S. Environmental Protection Agency: Washington, DC.

7. European Commission and ENTEC UK Limited, *Quantification of emissions from ships associated with ship movements between ports in the European Community, DG ENV.C1,*. 2002, European Commission: Brussels.

8. Carlton, J.S., et al., *Marine Exhaust Emission Research Programme, Report,*. 1995, Lloyd's Registry, England: London.

9. Skjolsvik, K.O., A.B. Andersen, and et al, *Study of Greenhouse Gas Emissions from Ships (MEPC 45/8 Report to International Maritime Organization on the outcome of the IMO Study on Greenhouse Gas Emissions from Ships)*. 2000, MARINTEK Sintef Group, Carnegie Mellon University, Center for Economic Analysis, and Det Norske Veritas: Trondheim, Norway.

10. International Maritime Organization, *Annex VI of MARPOL 73/78 Regulations for the Prevention of Air Pollution from Ships and NOx Technical Code*. 1998, London: International Maritime Organization. 150.

11. Sierra Research, *Support Document for the Control of Emissions from Marine Vessels Entitled Inventory of Air Pollutnat Emissions from Marine Vessels*. 1991, Sierra Research: Sacramento, CA.

12. Branch, A.E., *Elements of Shipping*. 7th ed. 2005, Milton Park: Routledge. 531.

13. Donovan, A. and J. Bonney, *The Box that Changed the World*. 2006, East Windsor: Commonwealth Business Media. 262.

14. Leach, P., *The World is a Box*, in *50 Years of Containerization*. 2006. p. 50.

15. Levinson, M., *The Box - How the Shipping Container Made the World Smaller and the World Economy Bigger*. 2006, Princeton: Princeton University Press. 376.

16. Hays, S.P., *Environmental Political Culture and Environmental Political Development.* Environmental History Review, 1992(Summer 1992): p. 1-22.

17. Dwyer, J. and M.F. Bergsund, *Dwyer and Bergsund Federal Environmental Laws Annotated*. 1998: West Group. 2025.

18. International Maritime Organization. *MARPOL Annex VI Ratifications*. [internet explorer] 2002 [cited 2002 08/2002]; Available from: www.imo.org.

19. U.S. EPA, *Emission Standards for New Marine Diesel Engines*. 2002, U.S. Environmental Protection Agency: Ann Arbor. p. 1-6.

20. California Air Resources Board and South Coast Air Quality Management District, *Air Quality Impacts from NOx Emissions of Two Potential Marine Vessel Control Strategies in the South Coast Air Basin*. 2000, California Air Resources Board: Sacramento. p. 133.

21. CARB. *California Air Resources Board*. 2003 [cited 2003 April 2003]; Available from: www.arb.ca.gov.

22. TRC Environmental Consultants, *Ship Emissions Control Study for the Ports of Long Beach and Los Angeles, Volume I: Marine Vessel Emissions While Hotelling in Port*. 1989, Port of Long Beach, Port of Los Angeles, South Coast Air Quality Management District, Western States Petroleum Association: Missions Viejo, CA.

23. Clean Air Task Force and Bluewater Network and Coalition for a Safe Environment, *Review of MARPOL Annex VI and the NOx Technical Code - Strengthening Annex VI Limits for Shipping Emissions of Air Pollution*, E.F.f.T. European Environmental Bureau, Environment and North Sea Foundation, Seas at Risk, and Swedish NGO Secretariat on Acid Rain, Editor. 2006, International Maritime Organization, Sub-Committee on Bulk Liquids and Gases: London. p. 6.

24. Rosenberg, N., *Inside the Black Box Technology and Economics*. 1982, Cambridge: Cambridge University Press. 304.

25. Baumol, W.J. and W.E. Oates, *The Theory of Environmental Policy - Externalities, Public Outlays, and the Quality of Life*. 1975, Englewood Cliffs: Prentice-Hall. 272.

26. Kendall, L.C. and J.J. Buckley, *The Business of Shipping*. 7th ed. 2001, Centreville, MD: Cornell Maritime Press.

27. Churchill, R.R. and A.V. Lowe, *The Law of the Sea*. 3rd ed, ed. P.D. McGoldrick. 1999, Manchester: Juris Publishing. 494.

28. Bell, D.E., R.L. Keeney, and H. Raiffa, *Conflicting Objectives in Decisions*. 1977, New York: John Wiley & Sons. 442.

29. Gregory, R. and R.L. Keeney, *Creating Policy Alternatives Using Stakeholder Values.* Management Science, 1994. **40**(8): p. 15.

30. Hammond, J.S., R.L. Keeney, and H. Raiffa, *Smart Choices A Practical Guide to Making Better Decisions*. 1999, Boston: Harvard Business School Press. 244.

31. Keeney, R.L., H. Raiffa, and R.F. Meyer, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. 1976, New York: John Wiley & Sons. 569.

32. Zeckhauser, R.J., R.L. Keeney, and J.K. Sebenius, *Wise Choices Decisions, Games, and Negotiations*. 1996, Boston: Harvard Business School Press. 478.

33. Raiffa, H., *The Art and Science of Negotiation*. 1982, Cambridge: Harvard University Press. 373.

34. Kemp, R., *Environmental Policy and Technical Change*. 1997, Cheltenham: Edward Elgar Publishing Limited. 360.

35. Utterback, J.M., *Mastering the Dynamics of Innovation How Companies Can Seize Opportunities in the Face of Technological Change*. 1994, Boston: Harvard Business School Press. 253.

36. Layzer, J.A., *The Environmental Case - Translating Values into Policy*. 2002, Washington, D.C.: CQ Press. 372.

37. Agren, C., *Abatement Measures Investigated - Cost-effective to do more at sea compared to additional measures at shore side*, in *Acid News*. 2005. p. 16-18.

38. The Port of Los Angeles and The Port of Long Beach, *San Pedro Bay Ports Clean Air Action Plan Technical Report*. 2006, Port of Los Angeles and Port of Long Beach: Los Angeles and Long Beach. p. 264.

39. Entek, U.L., *European Commission Directorate General Environment - Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments*. 2005, Entek UK Limited: Cheshire, England. p. 42.

40. Los Angeles Harbor Department, *Memorandum of Understanding for the Use of Emission Reductions from Voluntary Commercial Cargo Ship Speed Reductions to Meet the Goals of the 1994 State Implementation Plan and the 1997 South Coast Air Quality Management Plan for Marine Vessel Emissions Control Strategies*, C.A.R. Board, Editor. 2000, Port of Los Angeles: Port of Los Angels. p. 6.

41. Pitt, R. *Ships' Emissions Worry EC Environmentalists*. [internet explorer] 2002 [cited 2002 08/20/2002]; Available from: www.worldfuels.com/archive/european/euro011001.htm.

42. World Trade Organization, *International Trade Statistics 2009*. 2009, WTO: Geneva, Switzerland. p. 262.

43. Marine Transportation System Task Force, *An Assessment of the U.S. Marine Transportation System*. 1999, U.S. Department of Transportation: Washington DC. p. 122.

44. United Nations Conference on Trade and Development, *Review of Maritime Transport*. 2010. p. 192.

45. United Nations Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 2007*. 2007, UNCTAD: Geneva, Switzerland. p. 167.

46. United Nations Conference on Trade and Development, *Review of Maritime Transport*. 2005, UNCTD: Geneva. p. 134.

47. Salisbury, M., *About the Top 100.* The Journal of Commerce, 2010. **11**(22): p. 15A-30A.

48. National Retail Federation (NRF), *Celebrating 100 Years of Leadership - Annual Report 2010*. 2010, NRF: Washington D.C. p. 48.

49. National Retail Federation and Stores Magazine, *2008 Global Powers of Retailing - Standing out from the crowd*, F.T.S. Deloitte, Oracle Retail, Business Objects, Reflexis, STORES, Editor. 2008, STORES Magazine: Washington, D.C. p. 48.

50. NRF, N.R.F., *Global Powers of Retailing Top 250*, Delloite, Editor. 2011, NRF, Stores Magazine: Washington D.C. . p. 10-26.

51. Koch, C. *Port and Maritime Transportation Congestion Before the House Transportation and Infrastructure Committee and Subcommittee on Coast Guard and Maritime Transportation and Subcommittee on Water Resources*. 2001 May 23, 2001 [cited 2006 07/26/2007]; Available from: www.worldshipping.org.

52. U.S. Department of Transportation Bureau of Transportation Statistics, *U.S. International Trade and Freight Transportation Trends*. 2003, U.S. Department of Transportation: Washington DC.

53. World Shipping Council, *Partners in America's Trade*. 2002, World Shipping Council: Washington DC. p. 15.

54. Koch, C., *Meeting Presentation for the American Association of Port Authorities and the Intermodal Association of North America*. 2002, World Shipping Council: Washington DC. p. 9.

55. Miller., A.G., *Commercial Marine Activity for Deep Sea Ports in the United States*. 1999, Assessment and Modeling Division, Office of Mobile Sources, U.S. Envrionmental Protection Agency: Ann Arbor, MI. p. 214.

56. Bluewater Network. *Need for US Ratification of International Ship Air Pollution Treaty*. [Memorandum] 2006 [cited 2007 May 2007]; Available from: http://www.bluewaternetwork.org/reports/cv/annexIVfactsheet.pdf.

57. Solomon M.D., M.P.H., Gina M.; Todd R. Campbell, M.E.S., M.P.P.; Tim Carmichael; Gail Ruderman Feuer; Janet S. Hathaway, *Exhausted By Diesel - How America's Dependence on Diesel Engines Threatens Our Health*. 1998, NRDC Publications Department: New York, N.Y. p. 50.

58. Cofala, J., et al., *Analysis of Policy Measures to Reduce Ship Emissions in the Context of the Revision of the National Emissions Ceilings Directive*. 2007, International Institute for Applied Systems Analysis (IASA): Laxenburg, Austria. p. 74.

59. International Maritime Organization. *Marine Environment Protection Committee progresses key issues*. [Briefing #26] 2007 July 20, 2007 [cited 2007 08/2007]; Available from: www.imo.org.

60. International Maritime Organization. *New Rules to Reduce Emissions from Ships Enter into Force*. [Briefing #23] 2005 May 18, 2005 [cited 2006 June 2006]; Available from: www.imo.org.

61. *Clean Air Act*. 1990. p. 800.

62. Streets, D.G., G.R. Carmichael, and R.L. Arndt, *Sulfur Dioxide Emissions and Sulfur Deposition From International Shipping in Asian Waters.* Atmospheric Environment, 1997. **31**(10): p. 1573-1582.

63. Streets, D.G., S.K. Guttikunda, and G.R. Carmichael, *The Growing Contribution of Sulfur Emissions from Ships in Asian Waters 1988-1995.* Atmospheric Environment, 2000. **24**(26): p. 4425-4439.

64. Corbett, J., *Commercial Marine Vessel Inventory Review and Preparataion for the Northwest U.S.* 2001, Washington Department of Ecology: Olympia, WA. p. 18.

65. Corbett, J.J., James J. Winebrake, Erin H. Green, Prasad Kasibhatla, Veronika Eyring, and Axel Lauer, *Mortality from Ship Emissions: A Global Assessment.* Environmental Science & Technology, 2007: p. 7.

66. Friedrich, A., Heinen, Falk, Kamakate, Fatumata, Kodjak, Drew;, *Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships: Impacts, Mitigation Options, and Opportunities for Managing Growth*, K. Ha, Jeong, Dr. Youngil, Lloyd, Dr. Alan C., Walsh, Michael P.;, Editor. 2007, ICCT, The International Council on Clean Transportation;: Washington, D.C. .

67. U.S Environmental Protection Agency. *Health and Environmental Effects of NOx*. [internet explorer] 1997 07/2002 [cited 2002 07/2002]; Available from: www.epa.gov/ttn/oarpg/naaqsfin/noxhealth.html.

68. Berisa, M., *Innovation - Research & Development - Wallenius Fights NOx Emissions with Wartsila Wetpac*, in *Twentyfour7. Wartsila Stakeholder Magazine*. 2007. p. 79.

69. Davis, D.D. and e. at., *Impact of Ship Emissions on Marine Boundary Layer NOx and SO2 Distributions Over the Pacific Basin.* Geophysical Research Letters, 2001. **28**(2): p. 235-238.

70. Entek, U.L., *European Commission Directroate General Environment - Service Contract on Ship Emissions: Assignment Abatement and Market-based Instruments - Task 2b - NOx Abatement*. 2005, Entek UK Limited: Cheshire, England. p. 60.

71. Hellen, G., *Guide to Diesel Exhaust Emissions Control*, in *Marine News*. 2003. p. 22-25.

72. Docent, P.K. and A. Akademi, *NOx Emission Formation in Marine Diesel Engines - Towards a Quantitative Understanding*, in *Marine News*. 2003. p. 18-21.

73. P. Kasibhatla, e.a., *Do Emissions from Ships Have a Significant Impact on Concentrations of Nitrogen Oxides in the Marine Boundary Layer?* Geophysical Research Letters, 2000. **27**(15): p. 2229-2233.

74. Wartsila, *Air Emissions Legislation Review for Internal Combustion Engines*. 2003, Wartsila: Vaasa, Finland. p. 11.

75. EEB, T.E.E.B., The European Fderation for Transport and Environment (T&E), Seas At Risk (SAR), and the Swedish NGO Secretariat on Acid Rain, *Air Pollution from Ships*. 2004, EEB: Sweden. p. 15.

76. EPA, U.S.E.P.A., *NOx - How Nitrogen Oxides Affect the Way We Live and Breathe*. 1998, U.S. EPA: Research Triangle Park, NC. p. 6.

77. ISO, *International Standarad, Petroleum Products - Fuels (class F) - Specifications of Marine Fuels*. 1987, Geneva: International Organization for Standardization.

78. ISO, *International Standard, Petroleum Products - Fuels (class F) - Classification - Part I: Categories of Marine Fuels*. 1986, Geneva, Switzerland: International Organization for Standardization.

79. U.S. Environmental Protection Agency. *Health and Environmental Effects of SO2*. [internet explorer] 1997 07/2002 [cited 2002 07/15/2002]; Available from: www.epa.gov/ttn/oarpg/naaqsfin/so2health.html.

80. World Resources Institute. *Health Effects of Air Pollution*. [internet explorer] 1998-1999 07/2002 [cited 2002 07/2002]; Available from: www.igc.org/wri/wr-98-99/airpoll.htm.

81. World Health Organization (WHO), *Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide*. 2003, WHO: Bonn, Germany. p. 98.

82. American Lung Association (ALA), *Selected Key Studies on Particulate Matter and Health: 1997-2001*. 2001, American Lung Association: Washington D.C. p. 21.

83. EPA, U.S.E.P.A., *The Particle Pollution Report - Current Understanding of Air Quality and Emissions through 2003*. 2004, U.S. EPA: Research Triangle Park, NC. p. 28.

84. U.S. EPA Office of Air & Radiation and Office of Air Quality Planning & Standards. *Health and Environmental Effects of Particulate Matter*. [internet explorer] 1997 7/11/2002 [cited 2002 7/2002]; Available from: www.epa.gov/ttn/oarpg/naaqsfin/pmhealth.html.

85. World Resources Institute. *Urban Air: Health Effects of Particulates, Sulfur Dioxide, and Ozone*. [internet explorer] 1998-1999 07/2002 [cited 2002 07/2002]; Available from: www.igc.org/wri/wr-98-99/urbanair.htm.

86. Liu, D.H. and B.G. Liptak, *Air Pollution*. 1st ed. 1999: CRC Press. 256.

87. Acurex, *Analysis of Marine Emissions in the South Coast Air Basin*. 1997, Acurex Environmental Corporation: Mountain View, CA.

88. Capaldo, K., et al., *Effects of Ship Emissions on Sulphur Cycling and Radiative Climate Forcing over the Ocean.* Nature, 1999. **400**: p. 743-746.

89. Corbett, J.J. and P.S. Fischbeck, *International Technology Policy - Challenges in Regulating Ship Emissions*, in *Improving Regulation - Cases in Environment, Health, and Safety*, P.a.R.S.F. Fischbeck, Editor. 2001, Resources for the Future: Washington D.C. p. 282-309.

90. Laurence, C.A., *Vessel Operating Economies*. 1990, Coulsdon, Surrey: Fairplay Publications. 55.

91. MAN, B.W.D., *Propulsion Trends in Container Vessels*. 2005, MAN B&W Diesel A/S: Copenhagen, Denmark. p. 16.

92. Fairplay, L.s.R.-. *Lloyd's Regsitry of Ships*. 2001, Lloyd's Registry - Fairplay: London.

93. Fairplay, L.s.R.-. *World Fleet Statistics*. 2002, London: Lloyd's Registry.

94. Line, M. *Namegiving of Newbuilding L 203 from Odense Steel Shipyard*. [Press release] 2006 August 2006 [cited 2006 August 12, 2006]; Available from: media.maersk.com/en/PressReleases/2006/namegiving+L203.htm.

95. Mikkelsen, B., *"Emma Maersk" - The World's Largest*, in *Scandanavian Shipping Gazette*. 2006. p. 2.

96. Calder, N., *Marine Diesel Engines - Maintenance, Troubleshooting, and Repair*. 3rd ed. 2006: The McGraw-Hill Companies. 256.

97. Evangelista, J., *Big Diesel Balancing Act*, in *Surveyor: Quarterly Magazine from American Bureau of Shipping*. 2002. p. 14-22.

98. Woodyard, D., *Pounder's Marine Diesel Engines: and Gas Turbines*. 8th ed. 2004: Elsevier Science & Technology Books. 912.

99. Juoperi, K., *Heavy Fuel Oil - Still the Dominant Fuel Quality for Diesel Engines*, in *Marine News*. 2004. p. 12-14.

100. Lubrizol. *Ready Reference for Lubricant and Fuel Performance*. [internet explorer] 2001 [cited 2002 07/15/2002]; Available from: www.lubrizol.com/ReadyReference/EngineOils/12-Marine/default.htm.

101. Starcrest Consulting Group LLC, *Evaluation of Low Sulfur Marine Fuel Availability - Pacific Rim*. 2005, Port of Los Angeles: Los Angeles. p. 80.

102. Brubaker, N. and G.D. Eley, *Marine Fuels: Burning Crude's Leftovers*, in *Surveyor*. 1992. p. 2-7.

103. Corbett, J.J. and P.S. Fischbeck, *Commercial Marine Emissions and Life-Cycle Analysis of Retrofit Controls in a Changing Science and Poicy Environment*. 1999.

104. James J. Corbett and Horst W. Koehler, *Updated Emissions from Ocean Shipping.* Journal of Geophysical Research, 2003. **108**(D20): p. 4650.

105. Vig, N.J. and M.E. Kraft, *Environmental Policy from the 1970s to the Twenty-First Century*, in *Environmental Policy - New Directions for the Twenty-First Century*, N.J.M.E.K. Vig, Editor. 2003, CQ Press: Washington D.C. p. 436.

106. Kolstad, C.D., *Environmental Economics*. 2000, New York: Oxford Universtiy Press. 400.

107. Portney, P.R. and R.N. Stavins, *Public Policies for Environmental Protection*. 2nd ed. 2000, Washington DC: Resources for the Future. 281.

108. Kingdon, J.W., *Agendas, Alternatives, and Public Policies*. 2 ed. 2003, New York: Addison-Wesley Educational Publishers, Inc. 253.

109. Stone, D., *Policy Paradox - The Art of Political Decision Making*. 2002, New York: W.W. Norton. 428.

110. Helm, D., ed. *Environmental Policy - Objectives, Instruments, and Implementation*. 2000, Oxford University Press: Oxford. 324.

111. Rosenbaum, W.A., *Environmental Politics and Policy*. 2nd ed. 1991, Washington D.C.: Congressional Quarterly Inc. 336.

112. Dunlap, R. and K.D.V. Liere, *"The 'New Environmental Paradigm': AProposed Measuring Instrument and Preliminary Results".* Journal of Environmental Education, 1978. **9**: p. 19.

113. Smith, Z.A., *The Environmental Policy Paradox*. 4th ed. 2004, Upper Saddle River, NJ: Prentice Hall. 295.

114. English, M.R., et al., *Overview*, in *Tools to Aid Environmental Decision Making*, V.H.D.a.M.R. English, Editor. 1998, Springer: New York, NY. p. 342.

115. Simon, J.L., *Resources, Population, Environment: An Oversupply of False Bad News.* Science, 1980. **208**(27): p. 1431-1437.

116. Dryzek, J.S. and D. Schlosberg, eds. *Debating the Earth: The Environmental Politics Reader*. 1998, Oxford University Press: Oxford. 609.

117. Byrne, J., L. Glover, and e. Cecilia Martinez, *Environmental Justice: Discourses in International Political Economy*. 2002, New Brunswick, NJ: Transaction Publishers.

118. Saint-Simon, H., *Selected Writings on Science, Industry and Social Organization*. 1975, London: Croom Helm.

119. Simon, H.A., *Technology and Environment.* Management Science B (Applications), 1973. **19**(10): p. 1110-1121.

120. Beck, U., *From Industrial Society to the Risk Society: Questions of Survival, Social Structure, and Ecological Enlightenment*, in *Debating the Earth: The Environmental Politics Reader*, J.S.D.a.D. Schlosberg, Editor. 1998, Oxford University Press: Oxford. p. 327-346.

121. Chareonwongsak, K., *Globalization and Technology: How will they change society?* Technology in Society, 2002. **24**: p. 191-206.

122. Drucker, P.F., *Post-Capitalist Society*. 1993, New York: Harper Collins Publishers.

123. Foster, J.B., *The Vulnerable Planet A Short Economic History of the Environment*. 1999, New York: Cornerstone Books. 168.

124. Freeman, C. and L. Francisco, *As Time Goes By: From the Industrial Revolutions to the Information Revolution*. 2002, Oxford: Oxford University Press. 432.

125. Gare, A.E., *Postmodernism and the Environmental Crisis*. 1st ed. 1995, London: Routledge. 204.

126. Harvey, D., *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*. 1989, Malden, MA: Wiley-Blackwell. 392.

127. Kumar, K., *Prophecy and Progress: The Sociology of Industrial and Post-Industrial Society*. 1978, New York: Penguin Books.

128. Tatenhove, J.v., B. Arts, and P. Leroy, eds. *Political Modernisation and the Environment*. Vol. 24. 2000, Kluwer Academic Publishers: Dordrecht, The Netherlands. 219.

129. Acs, Z.J. and D.B. Audretsch, *Innovation and Technological Change An International Comparison*, ed. A.Z.J.a.D.B. Audretsch. 1991, Ann Arbor: The University of Michigan Press. 208.

130. Boland, M., *American Perspectives on Science and Technology Policy.* Technology in Society, 2002. **24**: p. 1-8.

131. Ellul, J., *The Technological Society*. 1964, New York: Alfred A. Knopf. 449.

132. Foray, D. and A. Grubler, *Technology and the Environment: An Overview.* Technological Forecasting and Social Change, 1996. **53**: p. 3-13.

133. Freeman, C. and L. Soete, *The Economics of Industrial Innovation*. 3rd ed. 1997, Cambridge: The MIT Press. 470.

134. Noble, D.F., *Present Tense Technology: Technology's Politics.* Democracy, 1983. **3**(2): p. 8-24.

135. Ruttan, V., *Technology and the Environment.* American Journal of Agricultural Economics, 1971. **53**: p. 707-717.

136. Barrett, J. and A. Scott, *The Ecological Footprint: A Metric for Corporate Sustainability.* Corporate Environmental Strategy 2001. **8**(4): p. 316-325.

137. Mokyr, J., *Twenty-five Centuries of Technological Change An Historical Survey*. Fundamentals of Pure and Applied Economics, ed. F.M. Scherer. 1990, Chur, Switzerland: Harwood Academic Publishers. 142.

138. Susskind, L.E., William Moomaw, and Kevin Gallagher, ed. *Transboundary Environmental Negotiation: New Approaches to Global Cooperation* 1st ed. 2002, Jossey-Bass: New York. 496.

139. Susskind, L.E., *Environmental Diplomacy: Negotiating More Effective Global Agreements* 1994, New York: Oxford University Press. 216.

140. Victor, D.G., Kal Raustiala, and Eugene B. Skolnikoff;, ed. *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice*. 1998, The MIT Press: Cambridge, MA. 686.

141. Vig, N.J. and R.S. Axelrod, eds. *The Global Environment - Institutions, Law, and Policy*. 1999, CQ Press: Washington D.C. 352.

142. IMO, I.M.O., *History of IMO*. 2011, IMO: London, England. p. 5.

143. IMO. *IMO History: IMO - What it is, what it does and how it works*. 2002 [cited 2002 08/2002]; Available from: www.imo.org.

144. IMO, I.M.O., *IMO Membership.* 2011: p. 2.

145. Mangone, G.J., *Shipping and Port Management*, M. Theis, Editor. 2002: Newark.

146. Marine Environment Protection Committee, M., IMO, *Amendments to the Annex of the Protocol of 1997 to Amend the International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto, Revised MARPOL Annex VI*. 2008, International Maritime Organization: London, England. p. 147.

147. Secretary;, T.O.o.t.P., *President Bush Signs H.R. 802 and H.R. 3891 into Law*. 2008, White House News: Washington D.C. p. 1.

148. Hellen, G., *A Brief Guide to Controlling Marine Diesel Exhaust Emissions*, in *Marine News*. 2005. p. 16-20.

149. International Maritime Organization, *New Rules to Reduce Emissions from Ships Enter into Force*, in *IMO Magazine*. 2005. p. 6.

150. International Maritime Organization. *Marine Environmental Protection Committee (MEPC), 53rd session: 18-22 July 2005*. 2005 July 2005 [cited 2006 July 2006]; Available from: www.imo.org.

151. Garelick, B. *Memorandum June EPA SECA Update*. [Memorandum] 2007 [cited 2007 May 2007]; Available from: http://www.westcoastdiesel.org/files/sector-marine/June%202005%20EPA%20SECA%20update.pdf.

152. International Maritime Organization. *Sub-Committee on Bulk Liquids and Gases (BLG), 10th sessions: 3-7 April 2006*. 2006 April 2006 [cited 2006 July 2006]; Available from: www.imo.org.

153. IMO;, *Sub-Committee on Bulk Liquids and Gases (BLG), 11th Session: 16-20 April 2007*. 2007, International Maritime Organization: London. p. 3.

154. IMO;, *Marine Environment Protection Committee (MEPC), 56th Session: 9-13 July 2007*. 2007, International Maritime Organization: London. p. 4.

155. International Maritime Organization. *The International Response*. [website] 2003 [cited 2003 4 May 2003]; Available from: http://globallast.imo.org/print.asp?page=internat_response.htm&menu=true.

156. IMO;, *Sub-Committee on Bulk Liquids and Gases (BLG), 12th Session: 4-8 February 2008*. 2008, International Maritime Organization: London. p. 4.

157. IMO;, *Marine Environment Protection Committee (MEPC) - 57th Session: 31 March - 4 April 2008*. 2008, International Maritime Organization: London. p. 4.

158. EPA, *Designation of North American Emission Control Area to Reduce Emissions from Ships*, O.o.T.a.A. Quality, Editor. 2010, Environmental Protection Agency: Washington D.C. p. 3.

159. Bryner, G.C., *Blue Skies Green Politics The Clean Air Act of 1990 and Its Implementation*. 2 ed. 1995, Washington D.C.: Cogressional Quarterly Inc. 280.

160. Agency;, U.S.E.P., *Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder - 40 CFR Parts 9 and 94*. 2007, Federal Register - National Archives and Records Administration: Washington D.C. p. 69522-69552.

161. Agency;, U.S.E.P., *Advance Notice of Proposed Rulemaking for Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder*. 2007, Office of Transportation and Air Quality: Washington D.C. . p. 3.

162. Agency;, U.S.E.P., *Change in Deadline for Rulemaking to Address the Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder - 40 CFR Part 94*. 2007, Federal Register - National Archives and Records Administration: Washington D.C. p. 68518-68525.

163. Agency;, U.S.E.P., *Change in Deadline for Rulemaking to Address the Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder - 40 CFR Part 94*. 2007, Federal Register - National Archives and Records Administration: Washington D.C. . p. 20948-20980.

164. Agency;, U.S.E.P., *Change in Regulatory Deadline for Rulemaking to Address the Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder*. 2007, Office of Transportation and Air Quality: Washington D.C. p. 2.

165. Agency;, U.S.E.P., *Change in Regulatory Deadline to Set Emissions Standards for New Marine Engines at or Above 30 Liters per Cylinder*. 2007, Office of Transportation and Air Quality: Washington D.C. p. 2.

166. U.S Environmental Protection Agency, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines*. 2009, Office of Transportation and Air Quality, U.S. EPA: Washington D.C. p. 527.

167. U.S Environmental Protection Agency, *40 CFR Parts 80, 85, 86, et al. Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Final Rule*, R.a. Regulations, Editor. 2010, Federal Register Washington D.C. . p. 22895-23065.

168. Theis, M., et al., *The Role of Technology in Achieving Environmental Policy Goals in the MTS.* Transportation Research Record 2004(1871): p. 42-49.

169. Sterner, T., *Policy Instruments for Environmental and Natural Resource Management*. 2003, Washington D.C.: Resources for the Future. 504.

170. Ripley, R.B. and D.D. McCool, *Public policy theories, models and concepts: An anthology*. 1996, New Jersey: Prentice-Hall.

171. Dewees, D.N., C.K. Everson, and W.A. Sims, *Economic Analysis of Environmental Policies*. 1975, Toronto: University of Toronto Press. 175.

172. Norberg-Bohm, V., *Stimulating 'Green' Technological Innovation: An Analysis of Alternative Policy Mechanisms.* Policy Sciences, 1999. **32**: p. 13-38.

173. Simon, H.A., *Rational Decision Making in Business Organizations.* The American Economic Review, 1979. **69**(4): p. 493-513.

174. Cyert, R. and J. March, *A Behavioral Theory of the Firm*. 2nd ed. 1992, Malden, MA: Blackwell Publishers Inc. 264.

175. Martin, R.L., *The Virtue Matrix Calculating the Return on Corporate Responsibility*, in *The Harvard Business Review*. 2002. p. 68-75.

176. Atkinson, G., *Measuring Corporate Sustainability.* Journal of Environmental Planning and Management, 2000. **43**(2): p. 235-252.

177. California Air Resources Board (CARB), C.E., *Final Statement of Reasons for Rulemaking - Including Summary of Comments and Agency Responses*. 2008, CARB: Sacramento, CA. p. 73.

178. California Air Resources Board (CARB), *Final Regulation Order - Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline*. 2009, CARB: Sacramento, CA. p. 20.

179. California Air Resources Board (CARB), *Updated Informative Digest - Regulations for Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline*. 2009, CARB: Sacramento, CA. p. 9.

180. Khalil, T., *Management of Technology - The Key to Competitiveness and Wealth Creation*. 2000, Boston: McGraw-Hill. 483.

181. Mokyr, J., *The Lever of Riches*. 1990, New York: Oxford University Press, Inc. . 349.

182. Mumford, L., *Technics and Civilization*. 1934, New York: Harcourt, Brace and Co. . 477.

183. Noble, D.F., *America by Design Science, Technology, and the Rise of Corporate Capitalism*. 1977, Oxford Oxford University Press. 384.

184. Rosenberg, N., *Technology and American Economic Growth*. 1972, Armonk, NY: M E Sharpe Inc. 211.

185. Rosenberg, N., *Exploring the Black Box: Technology, Economics, and History*. 1994, Cambridge, MA: Cambridge University Press. 284.

186. Rosenberg, N., *Technology and the Wealth of Nations*. 1992, Stanford: Stanford University Press. 460.

187. Rosenberg, N., *How the West Grew Rich: The Economic Transformation of the Industrial World*. 1987: Westview Press. 368.

188. Schumpeter, J.A., *Capitalism, Socialism, and Democracy*. (1942)1975, New York: Harper and Row. 460.

189. Easterbrook, G., *A Moment on Earth: The Coming Age of Environmental Optimism*. 1995, New York: Viking Penguin.

190. Starr, C. and R. Rudman, *Parameters of Technological Growth.* Science, 1973. **182**(October 26): p. 358-364.

191. Arrow, K.J., *Collected Papers of Kenneth J. Arrow: The Economics of Information*. Vol. 4. 1984, New York: Belknap Press. 296.

192. Advanced Cleanup Technologies Incorporation, *Advanced Maritime Emissions Control System (AMECS)*. 2006, ACTI: Rancho Dominguez, CA.

193. Solow, R.M., *Growth Theory: An Exposition*. 2nd ed. 2000, Oxford: Oxford University Press. 224.

194. Utterback, J.M., *Innovation in Industry and the Diffusion of Technology.* Science, 1974. **183**(4125): p. 620-626.

195. Weale, A., *Politics of Ecological Modernization*, in *Debating the Earth: The Environmental Politics Reader*, J.S.D.a.D. Schlosberg, Editor. 1998, Oxford University Press: Oxford. p. 301-318.

196. Mansfield, E., W. Bruce Allen, and Neil Doherty;, *Managerial Economics: Theory, Applications, and Cases*. 6th ed. 2004, New York: W.W. Norton. 920.

197. Cohen, M.D., *Organizational Learning*. 1995, Thousand Oaks, CA: Sage Publications, Inc. . 632.

198. Simon, J., *Developing decision-making skills for business*. 2000, Armonk, NY: M.E. Sharpe. 229.

199. Rosenberg, N., *Chemical Engineering as a General Purpose Technology*, in *General Purpose Technologies and Economic Growth*, E. Helpman, Editor. 1998, The MIT Press: Cambridge. p. 311.

200. Susskind, L.E., R.K. Jain, and A.O. Martyniuk, *Better Environmental Policy Studies - How to Design and Conduct More Effective Analysis*. 2001, Washington: Island Press. 187.

201. Rosenbaum, W.A., *The Politics of Environmental Concern*. 1973, New York: Praeger Publishers. 298.

202. National Retail Federation (NRF), *Big on Retail - Annual Report 2007*. 2007, NRF: Washington, D.C. p. 44.

203. NRF, N.R.F.a.S.M., *2008 Global Powers of Retailing - Standing out from the crowd*, F.T.S. Deloitte, Oracle Retail, Business Objects, Reflexis, STORES, Editor. 2008, STORES Magazine: Washington, D.C. p. 48.

204. Salisbury, M., *Growth Market - About the Top 100.* The Journal of Commerce, 2007. **8**(21): p. 5A, 16A-24A.

205. Business for Social Responsibility, *Sustainable Product Transportation - Clean Cargo Green Freight*. 2001, BSR: San Francisco. p. 4.

206. Diesel Technology Forum. *Scope of Marine Diesel Applications*. [internet explorer] 2002 [cited 2002 9/8/2002]; Available from: www.dieselforum.org/background/marineapplications.htm.

207. Salisbury, M., *About the Top 100.* The Journal of Commerce, 2008. **9**(21): p. 12A-42A.

208. Fankhauser, S., *World's First Common-Rail Low-Speed Engine Goes to Sea*, in *Marine News*. 2001. p. 12-15.

209. Heim, K., *Forward Look at Future Emissions Control Measures for Sulzer RTA Engines*, in *Marine News*. 2001. p. 16-19.

210. Kytola, J.a.D.P., *Successful Features of the Wartsila Common Rail*, in *Marine News*. 2005. p. 25-29.

211. Global Reporting Initiative, *Sustainability Reporting Guidelines*. 1999-2000, WRI: London. p. 104.

212. Global Reporting Initiative, *GRI Guidelines: Sustainability Reporting Guidelines*. 1999-2001, GRI: London. p. 104.

213. Hock, R.I.v., *From Reversed Logistics to Green Supply Chains.* Supply Chain Management, 1999. **4**(3): p. 129-135.

214. Kassaye, W.W., *Green Dilemma.* Marketing Intelligence & Planning, 2001. **19**(6): p. 444-455.

215. Laferty, W.M., *The Politics of Sustainable Development: Global Norms for National Implementation*, in *Debating the Earth: The Environmental Politics Reader*, J.S.D.a.D. Schlosberg, Editor. 1998, Oxford University Press: Oxford. p. 265-284.

216. Paehlke, R., *Environmental Values for a Sustainable Society: The Democratic Challenge*, in *Debating the Earth: The Environmental Politics Reader*, J.S.D.a.D. Schlosberg, Editor. 1998, Oxford University Press: Oxford. p. 147-161.

217. Sterner, T., *The Market and the Environment The Effectiveness of Market-Based Instruments for Environmental Reform*. 1999, Northampton: Edward Elgar Publishing, Inc. 488.

218. EPA, *Nonroad Engine and Vehicle Emission Study - Report.* 1991, United States Environmental Protection Agency: Washington, DC.

219. Charmley, B., *U.S. EPA Marine Update*. 2005, U.S. EPA Office of Transportation and Air Quality.

220. Hottenstein, L.N., *Ship Emissions Control Study for the Ports of Long Beach and Los Angeles: Marine Vessel Emissions While Hotelling in Port and Evaluation of Alternative NOx Control Technologies*. 1991, TRC Environmental Consultants, Inc.: Mission Viejo, CA.

221. Nall, S., *Plugged In.* The Journal of Commerce, 2007. **8**(26): p. 28-32.

222. NOAA, *Intercontinental Transport and Chemical Transformation (ITCT): A Research Activity within the International Global Atmospheric Chemistry Program (IGAC), White Paper*. 2001, National Ocean Atmospheric Administration: Boulder, CO. p. 35.

223. Port of Los Angeles, e.a., *Control of Ship Emissions in the South Coast Air Basin: Assessment of the Proposed Federal Implementation Plan Ship Fee Emission Fee Program*. 1994, Port of Los Angeles: Los Angeles, CA.

224. Entek, U.L., *European Commission Directorate General Environment - Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments - Task 2c - SO2 Abatement*. 2005, Entek UK Limited: Cheshire, England. p. 48.

225. Entek, U.L., *European Commission Directorate General Environment - Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments - Task 2a - Shore-side Electricity*. 2005, Entek UK Limited: Cheshire, England. p. 54.

226. Zoltan J. Acs and David B. Audretsch, *Innovation and Technological Change - An International Comparision*. 1991, Ann Arbor: The University of Michigan Press. 208.

227. Land & Sea Systems, *Guide to Exhaust Emissions Control Options*. 1999, International Council on Combustion Engines (CIMAC): Bristol. p. 41.

228. Rosgren, C.-E., *Common Rail on Wartsila Four-Stroke Engines*, in *Marine News*. 2001. p. 20-23.

229. Green, P.E. and V.R. Rao, *Conjoint measurement for quantifying judgemental data.* Journal of Marketing Research, 1971. **8**: p. 355-363.

230. Green, P.E. and V. Srinivansan, *Conjoint Analysis in Consumer Research: Issues and Outlook.* Journal of Consumer Research, 1978. **5**: p. 103-123.

231. Green, P.E., A.M. Krieger, and Y. Wind, *Thirty Years of Conjoint Analysis: Reflections and Prospects.* Interfaces, 2001. **31**(3): p. S56-S73.

232. Green, P.E. and Y. Wind, *A New Way to Measure Consumers' Judgements.* Harvard Business Review, 1975. **53**: p. 107-117.

233. Johnson, R.M., *Trade-off Analysis of Consumer Values.* Journal of Marketing Research, 1974. **11**: p. 121-127.

234. Louviere, J.J., *Analyzing Decision Making Metric Conjoint Analysis*. Quantitative Applications in the Social Sciences (07-067), ed. M.S. Lewis-Beck. 1988, Iowa City: Sage Publications, Inc. . 95.

235. Bell, D.E., H. Raiffa, and A. Tversky, *Decision Making Descriptive, Normative, and Prescriptive Interactions*. 1988, Cambridge: Cambridge University Press. 623.

236. Bardach, E., *A Practical Guide for Policy Analysis*. 2000, New York: Chatham House Publishers. 102.

237. Raiffa, H., *Decisions Analysis Introductory Lectures on Choices under Uncertainty*. 1970, Menlo Park: Addison-Wesley. 309.

238. Yu, P.-L., *Multiple-Criteria Decision Making: Concepts, Techniques, and Extensions*, ed. A. Miele. 1985, New York: Plenum Press. 388.

239. Festervand, T.A., R.B. Kethley, and B.D. Waller, *The Marketing of Industrial Real Estate: Application of Taguchi Loss Functions.* Journal of Multi-Criteria Decision Analysis, 2001. **10**: p. 219-228.

240. Batsell, R.R. and J.J. Louviere, *Experimental Analysis of Choice.* Marketing Letters, 1991. **2**: p. 199-214.

241. Green, P.E., *On the Design of Choice Experiments Involving Multifactor Alternatives.* The Journal of Consumer Research, 1974. **1**: p. 61-68.

242. Raiffa, H., J. Richardson, and D. Metcalfe, *Negotiation Analysis The Science and Art of Collaborative Decision Making*. 2002, Cambridge: The Belknap Press of Harvard University Press. 548.

243. Luce, R.D. and J.W. Tukey, *Simultaneous Conjoint Measurement: A New Type of Fundamental Measurement* Journal of Mathematical Psychology, 1964. **1**: p. 1-27.

244. Carroll, J.D. *Categorical Conjoint Measurement*. in *Meeting of Mathematical Psychology*. 1969. Ann Arbor, MI.

245. Anderson, N.H., *Functional Measurement and Psychophysical Judgment.* Psychological Review, 1970. **77**: p. 153-170.

246. Bateson, J.E.G., D.J. Reibstein, and W. Boulding, *Conjoint Analysis Reliability and Validity: A Framework for Future Research.* Review of Marketing, 1987: p. 451-481.

247. Green, P.E. and V. Srinivasan, *Conjoint Analysis in Marketing: New Developments with Implications for Research and Practice.* Journal of Marketing, 1990. **54**: p. 3-19.

248. Wittink, D. and P. Cattin, *Commercial Use of Conjoint Analysis: An Update.* Journal of Marketing, 1989. **53**: p. 91-96.

249. Batsell, R.R. and L.M. Lodish, *A Model and Measurement Methodology for Predicting Individual Consumer Choice.* Journal of Marketing Research, 1981. **18**: p. 1-12.

250. Louviere, J.J. and G. Woodworth, *Design and Analysis of Simulated Consumer Choice or Allocation Experiments.* Journal of Marketing Research, 1983. **20**: p. 350-367.

251. Sower, V.E., M.J. Savoie, and S. Renick, *An Introduction to Quality Management and Engineering*. 1999, Upper Saddle River, NJ: Prentice Hall 235.

252. DeGarmo, P.E., J.T. Black, and R.A. Kohser, *Materials and Process in Manufacturing*. 8th ed. 1999, New York: John Wiley & Sons, Inc. 1259.

253. Ross, P.J., *Taguchi Techniques for Quality Engineering - Loss Function, Orthogonal Experiments, Parameter and Tolerance Design*. 2nd ed. 1996, New York: McGraw-Hill. 329.

254. Pruitt, D.G., *Negotiation Behavior*. 1981, New York: Academic Press. 263.

255. Anderson, D.R., T.A. Williams, and D.J. Sweeney, *Statistics for Business and Economics*. 10th ed. 2007, Mason, OH: South-Western. 1056.

256. Cohen, J. and P. Cohen, *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. 2nd ed. 1983, Mahwah, NJ: Lawrence Erlbaum Associates, Inc. .

257. Freedman, D., R. Pisani, and R. Purves, *Statistics* 4th ed. 2007, New York, NY: W.W. Norton & Company, Ltd. 578.

258. Kiemele, M.J., S.R. Schmidt, and R.J. Berdine, *Basic Statistics Tools for Continuous Improvement*. 4th ed. 1997, Colorado Springs: Air Academy Press. 250.

259. Winston, W.L., *Microsoft Excel Data Analysis and Business Modeling*. 2004, Redmond, WA: Microsoft Press. 602.

260. Mandel, J., *The Statistical Analysis of Experimental Data*. 1964, Mineola, NY: Dover Publications. 410.

261. Tabachnick, B.G. and L.S. Fidell, *Using Multivariate Statistics*. 2006, Boston, MA: Allyn & Bacon.

262. Ceres, *Ceres Sustainability Report 2006*. 2007, Ceres: Boston. p. 31.

263. Ceres-ACCA, *Report of the Judges - North American Awards for Sustainability Reporting 2007*. 2007, Ceres: Boston. p. 24.

264. Victor, D.G., K. Raustiala, and E.B. Skolnikoff, eds. *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice*. Global Environmental Accord: Strategies for Sustainability and Institutional Innovation, ed. N. Choucri. 1998, The MIT Press: Cabridge. 737.

265. Tabucanon, M.T., *Multiple Criteria Decision Making in Industry*, ed. P.R.W. Grubbstrom. Vol. 8. 1988, Amsterdam: Elsevier. 337.

Appendix A

TOP 20 LINER OPERATORS (OECD TRANSPORT DIVISION 2010)

Table A.1 Top 20 Liner Operators (OECD Transport Division 2010)

Top 20 Liner Operators (Fully Cellular Fleet in TEU's)					
1	Maersk Line	1,746,639	11	MOL	348,353
2	MSC	1,507,843	12	K Line	325,280
3	CMA CGM Group	944,690	13	Yang Ming	317,304
4	Evergreen	592,732	14	OOCL	290,350
5	APL	524,710	15	Hamburg Sud	283,897
6	COSCON	495,936	16	HMM	259,941
7	Hapag-Lloyd Group	470,171	17	Zim	215,726
8	CSCL	457,126	18	CSAV	195,884
9	Hanjin	400,033	19	UASC	176,578
10	NYK	359,608	20	PIL	173,989
Top 20 World Liners (Total TEU's)		10,086,790			
Rest of World Fleet (Total)		4,864,981			

Appendix B

TOP 50 U.S. IMPORTERS OF CONTAINERIZED CARGO

Table B.1 Top 50 U.S. Importers of Containerized Cargo

RANK	COMPANY	RANK	COMPANY
1	Wal-Mart Stores	26	Kohl's
2	Target	27	Panasonic Corp. of North America
3	Home Depot	28	Pier 1 Imports
4	Dole Food	29	Williams-Sonoma
5	Sears Holding	30	Staples
6	Lowe's	31	Nestle USA/Nestle Waters
7	Costco Wholesale	32	Sony Corp. of America
8	LG Group	33	Toys "R" Us
9	Philips Electronics North America	34	Mattel
10	Heineken USA	35	Dollar General
11	Chiquita Brands Int'l.	36	Michaels Stores
12	Ashley Furniture Industries	37	Canon USA
13	IKEA International	38	Rooms to Go
14	Samsung Electronics America	39	Mercedes Benz/Daimler Trucks
15	JCPenney	40	Southern Wines & Spirits of America
16	Jarden	41	Toyota Tsusho America (TAI)
17	General Electric	42	Michelin North America
18	Red Bull North America	43	Best Buy
19	Nike	44	Macy's
20	Whirlpool	45	Anheuser-Busch
21	Family Dollar Stores	46	Hasbro
22	Gap Stores	47	Itochu International
23	Dollar Tree Stores	48	Electrolux
24	Big Lots	49	Arauco Wood Products
25	Dorel Industries	50	Adidas Group

JOURNAL OF COMMERCE – 2009

Appendix C

NOX ABATEMENT TECHNIQUES AND TECHNOLOGIES

The Formation and Abatement of Nitrogen Oxides in the Marine Engine

The powerful two-stroke diesel engine utilized on most container vessels for efficient, high-speed propulsion creates an internal environment of extremely high temperatures and pressures, both of which increase emissions [71, 96, 97, 102]. With regards to nitrogen oxides, the heat inside of an engine's combustion chamber forces molecular nitrogen in the air to oxidize and become oxides of nitrogen (NOx) [72]. Nitrogen oxide emissions (NOx) from diesel engines consist of mainly nitric oxide (NO) and nitrogen dioxide (NO2). "Nitric oxide from combustion originates from two sources: atmospheric nitrogen (N2) in the combustion air and organic nitrogen in the fuel. Typically, N2 is the most important source in diesel engines"[72]. Within the combustion chamber, hundreds of these complex thermal reactions occur, producing the high levels of NOx that are present in the vessel's exhaust [72, 97]. Therefore, reducing NOx from marine vessel operations requires either the establishment of a lower peak combustion chamber temperature – through direct adjustments to the engine processes (wet or dry primary methods) - or the utilization of techniques that address the exhaust itself - secondary methods that do not require changes to the engine [25, 55, 65, 68, 88-90]. The following tables provide a streamlined compilation of these different primary and secondary NOx abatement methods based on information collected from commercial marine engine manufacturers (Wartsila, MAN B&W, and Sulzer) as well as numerous containerized vessel operators and other vessel emissions focused research [39, 66, 68, 71, 74, 91, 148, 208-210, 228].

Exploratory NOx-reducing techniques

As is often the case, research into the development of the above NOx reducing techniques has also helped to encourage the introduction of new ideas and innovations. Another proposal, which is currently receiving a great deal of attention, comes from a California-based hazardous waste management firm – Advanced Cleanup Technologies Incorporated (ACTI) [192]. Their concept takes the process of SCR off of the vessel and puts it on the dock or a barge. The device, called the Advanced Maritime Emissions Control System (AMECS), is activated when a hood (the emissions intake bonnet EIB) placed over the exhaust stack funnels the ship's exhaust to an emission reduction system that follows a process similar to the onboard Selective Catalytic Reduction system. The benefit of this type of system – beyond the reduction percentages similar to onboard SCR systems - is that it can be used with any type of vessel and mandates no special requirements on the part of the vessel operator. The disadvantage is that it only reduces emissions in ports equipped with the technology and would do nothing to limit in transit emissions. Although this technology is still in the developmental stages, many groups, including ports and environmental advocates, hope that it will be commercially operational within the next five to ten years [192]

Table C.1 NOx Reduction Technologies – Primary

NOx Reduction Technologies				
Primary Wet	Introduces water into the combustion chamber to reduce the combustion temperature and further atomize the fuel			
Title	How It Works	NOx Reduction	Risks	Advantages
Direct Water Injection (DWI)	Electric pumps introduce fresh water under pressure (usually between 200-400 bars) to the combustion chamber immediately before the fuel	20 - 50% below IMO required levels Amount of NOx decreases in a one to one ratio (between 30 - 50%) as the concentration of water introduced into the combustion chamber increases	Risk of diluting or remove engine lubricants – causes engine wear or engine seizure Slight increases in particulates depending on the quality of fuel Requires that vessels have adequate onboard fresh water storage equipment	Requires little space and can be installed while the vessel is underway Can be retrofit Flexible – operator can turn on and off without changing engine performance

Table C.1 cont.

Water/Fuel Emulsion	Fresh water is emulsified with the fuel (fuel mills or homogenizers are employed) and then the mixture enters the combustion chamber The water mixed with the fuel creates a secondary atomization – burns the fuel more completely with less heat	20 - 50% below IMO required levels Amount of NOx decreases in a one to one ratio (between 30 - 50%) as the concentration of water introduced into the combustion chamber increases	Possibility of lowering the engine's maximum power capacity Requires that vessels have adequate onboard fresh water storage equipment	Can decrease particulate matter (up to 15%) No loss of lubricant cited Can be used with HFO or other types of residual fuel Flexible – operator can turn on and off without changing engine performance
Humid Air Motor (HAM)	Mixes heated intake (or charge) air augmented with water vapor from evaporated seawater with the combustion air to lower its temperature and reduce NOx	30-40% below IMO required levels May be capable of achieving decreases between 50 and 80%	Integrated into engine design – not suited for retrofit – best for new builds Requires appropriate onboard space and proper supplemental equipment	Generates no adverse impact on engine power capabilities May reduce fuel and lube oil use (regardless of fuel type) It can be employed simultaneously with other emission technologies, like water/fuel emulsion or direct water injection

Table C.1 cont.

NOx Reduction Technologies				
Primary Dry	Adjustments are made to engine properties such as engine power, fuel injection, compression ratios, valve mechanics, turbo efficiency, and cylinder pressures.			
Title	How It Works	NOx Reduction	Risks	Advantages
Electronic Engine Control	These units (often labeled - ECM, ECU, RT-flex, or ME) are programmed to simultaneously manage engine features - fuel injection, compression ratios, and intake and exhaust valves at various times, rates, and lengths	15 - 20% below IMO required levels Greater decreases (25 - 30%) possible but usually at the expense of higher fuel consumption	Incorrect changes can result in reduced fuel efficiency and an increase in emissions and particulates Technology is only feasible for new and near new (2000 and younger) vessels	Adjustments can be performed while the vessel is in service Flexibility - vessel operator has many available options or ‘operation modes’ that can be applied and changed
Fuel Injection Valves	Optimizes fuel injection and atomization (spray patterns, pressures, and timed valve movements) for high levels of efficiency in both fuel use and emission reductions	Around 20% below IMO required levels	Cannot be easily performed while the vessel is in service – typically performed when the vessel undergoes routine maintenance	More efficient slide valves are now standard on two-stroke marine diesels (the only type of engine capable of utilizing this technology) One of the easiest engine modifications for retrofit of older vessels

Table C.1 cont.

Common Rail Fuel Injection (CR)	Provides operators with complete control over fuel pressure and injection regardless of engine load - in CR these processes are maintained independent of the engine Fuel is stored in the "common rail" or fuel line until it is signaled to inject into the cylinders The combination of very high pressure and specialized injectors generates a mixture of air and fuel that can burn very efficiently	Around 30% below IMO required levels		Available for both two- and four-stroke engines Can reduce emissions and eliminate visible smoke without affecting engine operation or increasing fuel consumption Available for new construction or retrofit Can be used in combination with other reduction techniques without affecting engine operations

Table C.2 NOx Reduction Technologies - Secondary

NOx Reduction Technologies				
Secondary	Designed to address emissions in the exhaust after leaving the engine			
Title	How It Works	NOx Reduction	Risks	Advantages
Exhaust Gas Re-circulation (EGR)	Treats and cools a portion of the exhaust air and then re-introduces it to the engine's intake air prior to combustion – cooling and changing the composition of the air	40-50% below IMO required levels	Necessitates tools such as coolers, exhaust blowers, and scrubbers, all of which need to be properly maintained and positioned around the engine Use of low sulfur diesel fuel recommended	Reduces all pollutants of concern – nitrogen oxides, sulfur oxides, and particulates
Selective Catalytic Reduction (SCR)	Employs a catalyst such as ammonia or urea after the combustion chamber to break down NOx into benign emissions of nitrogen and water vapor (Gases enter the exhaust system, are injected with either ammonia or urea, and then are moved through a catalytic converter to break down the NOx in the exhaust into water vapor and nitrogen)	From 65 - 99% below IMO required levels	Increases operating costs - the purchase of ammonia or urea and the replacement costs of the catalyst Adds consumed space and weight to the engine room Many key ports or bunkering facilities do not currently offer a readily accessible supply of ammonia or urea Products (ammonia and urea) need to be stored and managed safely Recommends utilization of low sulfur diesel fuel (1.0% sulfur)	Greatest NOx reduction capabilities Reduces all pollutants of concern – nitrogen oxides, sulfur oxides, and particulates Can reduce PM by 30 - 40% Can be utilized either in new builds or as retrofit on two- or four-stroke engines

Appendix D

EXERCISE SCRIPT

You have been invited to participate in this exercise today because of your experience and knowledge in international container shipping. Many companies and organizations are becoming increasingly interested in the environmental impacts of global industries. Transportation of goods is often a large section of global production companies and retailers. The University of Delaware is currently working with industry to look into the various environmental impacts from this operation. Transportation of goods by water continues to be the most common and cost-effective means of moving cargo internationally. However, shipping contributes to important environmental problems, such as air pollution and water pollution. This exercise will help to better identify and evaluate various stakeholder perspectives for environmental policy changes and improvements regarding the transportation of goods by water.

Air emissions (specifically NOx, SO_2, and CO_2) from cargo transportation by ships have been found to have a significant negative impact on the air quality of communities surrounding ports, as well as the atmosphere in the open ocean. Various technological and operational improvements have been proposed to reduce air pollution from shipping. Adopting any of these alternatives will reduce the environmental impacts, but could affect both the vessel operator (Carrier) and the cargo shipper in terms of cost or service.

Companies and organizations involved in marine transportation of cargo are becoming aware of these factors, as are policymakers and advocates. We are considering possible designs for a *voluntary vessel emission reduction program*. Insight and opinions from all of you are necessary to form a complete policy picture.

Because the program is voluntary, you will only want to participate if the program has value to your company or organization. With this information, we can evaluate real strategies to improve the environmental performance of cargo transportation in terms of your preferences.

As stated previously, you have been selected to complete this exercise because you are representatives from a Shipper, a Carrier, a government agency, an NGO, or an industry or environmental advocate. Please circle on the information side which of these groups that you are associated with. If none of these categories applies to you please fill in your group or industry category in the space provided. Also, please mark the company division that you are representing: logistics, corporate responsibility, senior management, industry advocate, environmental advocate, operations, or policy maker. Again, if your company division or position is not provided, please write it in the space provided. Finally, please fill in the remaining items on the information side of the response sheet.

This exercise has two parts: First we ask you to take your own perspective regarding the environmental impacts, costs, and logistics of moving goods (If Shipper think Shipper/If Carrier think Carrier). Second, we ask you to change viewpoints and consider the Carrier's (vessel operator's) perspective (or Shipper if speaking to carrier audience).

On each of these 11 cards you will find a different hypothetical but realistic reduction technique. Each technique has slightly different attributes. The definitions for each of these attributes can be found on the sheet labeled ***Definitions***. With regards to the definitions, it is reasonable make a few assumptions. A high percent reduction is favored to a low percent reduction. Lower costs are preferred to higher costs. A time to adopt that is immediate is preferred to the next yard visit. A technique with no service effects is preferred to one that has revision to current logistics. A monitored certification is preferred to a calculated certification. Lastly, a technique that reduces other emissions is preferred to one that increases other emissions.

First, we will run this exercise from your organization's point-of-view. Flip the response sheet over to the side labeled ***Part One*** and ***Part Two***. Please arrange the 11 cards in order of your organization's preference – the most valuable technique being first and the least valuable being last. Please write your answers – the color associated with the hypothetical technique - in order in the Area labeled ***Part One.*** Second, what percentage of (Shippers, Carriers, Advocates or Policy makers) do you think would agree with the technique that you chose for your first choice? What percentage of (Shippers, Carriers, Advocates or Policy Makers) do you think would agree with the technique that you chose for your last choice? Write your answer in the spaces under ***% Agreement***. Next, focusing on the attributes, please arrange each of the seven attributes in order of your preference – most valuable being first and least valuable being last. Please enter your answers in the area labeled ***Attributes***.

Now, adopt the Carrier perspective. We are going to go through the same exercises again. Please arrange the cards once again, now putting the techniques – the colors - in the order that you believe that the Carriers would put them in. Please write your answers in the area labeled ***Part Two***. What percentage of Carriers do you think would agree with the technique that you chose for your first choice? What percentage of Carriers do you think would agree with the technique that you chose for you last choice? Please write your answer in the spaces under ***% Agreement***. Next, focusing on the attributes, please arrange each of the seven attributes in order of your preference – most valuable being first and least valuable being last. Please enter your answers in the area labeled ***Attributes.***

Appendix E

DEFINITIONS

% NOx Reduction: Percentage of pollutant (NOx) decrease from the vessel by utilizing option (For example 40% would mean that utilizing the option caused the NOx emissions from that vessel to decrease 40% from the emission levels from that vessel prior to the option)

Fixed Cost: One time payment necessary for equipment and all installation costs associated with the option

Annual Cost: Ongoing costs incurred for utilizing the option – maintenance, costs of new catalyst needed for emission reduction technology (for example, ammonia or urea that is required for SCR), or changes in levels of vessel inputs (for example, increasing fuel as a part of an emission reduction process would be an added cost)

Time to Adopt: Immediate – Do not need to make physical adjustments to the vessel that would require it to be out of service

Next Yard Visit: Physical adjustments to the vessel are required so the initiation/installation of the option would have to wait until the vessel was pulled out of service for its next routine yard visit (1 – 5 years)

Service Effects: None – Utilizing this option does not require any changes to current logistics (scheduled routes)

Revision to Current Logistics: Utilization of this option does require changes to the current logistics – additional route days, changes in cargo flows (for example service every two weeks rather than weekly service)

Verifiability: Calculated Certification – Emissions reduction and proper performance is verified indirectly through logs and calculations

Monitored Certification: Emissions reductions and proper performance are verified directly by monitoring equipment

Reduces Carbon Emissions: Yes – Utilizing this emission reduction option causes carbon (CO_2) emissions to decease and/or remain at the same level

No – Carbon (CO_2) emissions stay the same or increase slightly (2 – 3%)

Appendix F

HUMAN SUBJECTS REVIEW LETTER

Melissa Theis
College of Marine Studies
Marine Policy Program - Robinson Hall
University of Delaware
Newark, DE 19716

Dr. T. W. Fraser Russell
Vice Provost for Research
Chairman, Human Subjects Review Board
Office of the Vice Provost for Research
210 Hullihen Hall
University of Delaware
Newark, DE 19716

Dear Dr. Russell,

My name is Melissa Theis and I am currently a graduate student in the University of Delaware's Marine Policy program. My area of interest is marine transportation and policy, specifically studying the design, implementation, and enforcement capabilities for environmental policies in international container shipping.

This letter requests an exemption from review by the Human Subjects Review Board for graduate research. I believe that I qualify under the second research category – research involving the use of survey or interview procedures. This work does not seek to evaluate individuals themselves, but to characterize the perspectives of different stakeholder views within this industry. Once the information has been gathered, I will not identify individual human subjects, directly or indirectly. Published summaries of this work will not connect individual responses with particular companies. The type of data that I will be gathering will not place the subjects at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.
Here is some background on my Marine Policy topic and research design. Marine vessel transport continues to be the most widely utilized and cost-effective means of moving cargo for today's global markets and industries. However, characteristics implicit in international shipping make the application of traditional policies and programs extremely difficult. International waterborne trade operates in international waters, beyond most national jurisdictions. Without some kind of authority organization promulgating regulations to direct the industry, the best remaining options are to form an international treaty or an industry-based program.

Many international agreements have been designed and implemented within the shipping industry through the International Maritime Organization (IMO). Agreements dedicated to safety and training have proven to be very successful, whereas environmental agreements have struggled for acceptance.
Studies have revealed that air emissions (specifically NOx, SO_2, and CO_2) from vessels create a significant negative impact on the air quality of the communities surrounding ports, as well as the atmosphere in the open ocean. Efforts to try to reduce air emissions from vessels are quickly evolving into a topic of interest for these reasons.

My research assesses whether or not industry-based vessel emissions reduction programs could be possible. In order to design a successful initiative, the proposed program must have value to all participating parties. An important part of my research will involve assessing stakeholder preferences for various vessel emission reduction techniques. An exercise utilizing a Taguchi design method has been developed to enable me to determine stakeholder preferences. The exercise presents a participant with a set of eleven cards, where each card represents a hypothetical but realistic emission reduction technique. The individual is first asked to think from the point of view of their own stakeholder category (shipper (multi-national retailer), carrier (vessel operator), policy-maker (government agency or sea port), environmental or trade advocate (non-governmental organizations). Then, the participant is asked to put the set of cards in order of preference to his stakeholder group. The first card would represent their most valued technique and the last would represent their least valued technique. The second part of the exercise would ask the person to approximate what percentage of others within his/her same category (shippers, carriers, advocates, or policy makers) they think would, in general, agree with their first and last choice. The third portion of this exercise has the participant place the seven attributes used to define the techniques in order of their preference. The exercise then requests that the participants respond from the point of view of the carrier (vessel operator). The same set of questions is asked again.

I will run the exercise with representatives from each of the stakeholder groups (shipper, carrier, advocate, and policy maker). Within the shipper (multi-national retailer) category, I would focus on the top fifty U.S. importers of containerized cargo and involve sections such as logistics, corporate responsibility, and senior management. For the carriers (vessel operators), I would assess representatives from the top twenty global carriers, as reported by the Journal of Commerce. I plan to run the exercise on as many subjects as I can. I intend to recruit them through phone calls and also by word of mouth. I will probably arrange a meeting and invite several representatives so that I can perform the exercise with several different groups at one time.

The name of my advisor is Dr. James Corbett. Please, feel free to contact Dr. Corbett or myself with any questions that you might have.

Melissa Theis
College of Marine Studies
Marine Policy Program - Robinson Hall
University of Delaware
Newark, DE 19716