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A SOCIOTECHNICAL SYSTEMS APPROACH TO COASTAL MARINE SPATIAL PLANNING

by

Tyler B. McDonald

December 2016

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This thesis conducted a requirements analysis on the planning and permitting process for ocean aquaculture operations in the state of Hawaii, which is applicable to the other Pacific Islands within the jurisdiction of the Pacific Islands Regional Planning Body (PIRPB). The aim of the analysis was to form the basis for and generation of a set of capability requirement recommendations for a future Coastal Marine Spatial Planning (CMSP) decision-support system. All research, data collection, modeling, analysis, and recommendations were conducted from a systems engineering perspective and specifically used a sociotechnical systems approach. The research investigated aquaculture permitting from the perspective of the aquaculture companies that must navigate the process. Personnel from three Hawaiian aquaculture companies were interviewed. These interviews provided the bulk of the raw data that was used in subsequent analysis. This raw data was then honed by way of content analysis. From there the macroergonomic analysis and design methodology was adapted for use in analysis and generation of capability requirements for a decision-support system. The study resulted in the generation of 16 recommended requirements for the design of a coastal and marine spatial planning decision support tool.

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A SOCIOTECHNICAL SYSTEMS APPROACH TO COASTAL MARINE SPATIAL PLANNING

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LIST OF ACRONYMS AND ABBREVIATIONS

CDUP	Coastal District Use Permit
CMSP	Coastal Marine Spatial Planning
CZMP	Coastal Zone Management Plan
DLNR	Department of Land and Natural Resources
DOD	Department of Defense
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FFBD	functional flow block diagram
HNL	Honolulu
IRB	Institutional Review Board
LE	Loop Exit
LP	Loop
MARFORPAC	Marine Corps Forces Pacific
ME	macroergonomic
MEAD	macroergonomic analysis and design
NFWS	National Fish and Wildlife Service
NGO	Non-governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant and Discharge Elimination System
NPS	Naval Postgraduate School
NRP	Naval Research Program
OCCL	Office of Coastal Conservation and Lands
PI	primary investigator
PII	personally identifiable information
PIRO	Pacific Islands Regional Office
PIRPB	Pacific Islands Regional Planning Body
SE	systems engineering
STS	sociotechnical system

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GLOSSARY OF TERMS

Coastal Marine Spatial Planning—"An integrated, comprehensive, ecosystem-based, flexible, and proactive approach to planning and managing uses and activities. It identifies areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, and preserve critical ecosystem services to meet economic environmental, security, and social objectives" (Griffin 2015)

Content Analysis—A method of comparing and contrasting the responses from all interview participants in order to accurately summarize the responses.

Clustering—Forming perceptual wholes from things that are connected, belong together, or have common meanings, while separating them from things whose relationships seem accidental or meaningless (Krippendorff 2004).

Environment—Everything that is outside the boundaries of a system (Blanchard and Fabrycky 2006). The natural world (Webster's Dictionary 2009)

Functional Flow Block Diagram (FFBD)—A diagram "developed to describe the system and its elements in functional terms" (Blanchard and Fabrycky 2006).

Key Variance—Variances that that cause the greatest perturbations to the process and thus generate the most severe schedule delays and cost increases (Taylor and Felton 1993).

Macroergonomics—The design of work systems which focuses on organization-system interactions (Kleiner 2006).

Marine Aquaculture—The farming of fish, shellfish, kelp, algae, or other aquatic marine life in the ocean environment, normally in confined enclosures.

Role Network—A map of relationships between people and organizations within an organization and between the organization and its environment. (Taylor and Felton 1993)

Sociotechnical Systems—"A bounded, purposeful enterprise in a recognizable external environment that contains transformation (technical system) and people working together over time (social system)" (Taylor and Felton 1993).

System—An assemblage or combination of functionally related elements or parts forming a unitary whole, such as a river system or a transportation system (Blanchard and Fabrycky 2006).

Systems Engineering—An interdisciplinary approach and means to enable the realization of successful systems (Whalen et al. 2004).

Unit Operation—Transformation steps of a sociotechnical system (Taylor and Felton 1993).

Variance—Unexpected or unwanted deviation from standard operating conditions, specifications or norms (Emery and Trist 1978).

EXECUTIVE SUMMARY

The Pacific Islands Regional Planning Body (PIRPB) is concerned with potential conflicts that arise among the multitude of organizations that conduct activities and operations on and near the ocean in the U.S. affiliated Pacific Islands—Hawaii, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. This planning body has as its mission "to plan, coordinate, and realize all responsibilities described under Executive Order 13547, *Stewardship of the Ocean, Our Coasts, and Great Lakes*, commonly referred to as the National Ocean Policy. The Pacific Islands Regional Planning Body will create a coastal and marine spatial plan for effective conservation and sustainable use of natural and cultural resources for the benefit of the region, its indigenous people, and the nation" (Pacific Islands RPB n.d.). The creation of a coastal marine spatial plan is intended to provide a framework for more effective management of the ocean spaces.

A major goal of the PIRPB is the creation of a costal marine spatial plan that provides a framework for more effective management of the ocean spaces. The PIRPB described three general functions of coastal and marine spatial planning (Griffin 2015). These include:

1. Identify areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, and preserve critical ecosystem services to meet economic environmental, security, and social objective.
2. Provide an integrated, comprehensive, ecosystem-based, flexible, and proactive approach to planning and managing uses and activities.
3. Reduce or eliminate user conflicts, increased cost and delays from planning and regulatory inefficiencies, and the potential loss of critical economic, ecosystem, social, and cultural services for present and future generations. (Griffin 2015)

Additionally, the PIRPB lists the following roles and benefits for the military:

1. Further the National Ocean Policy as directed, by assisting in the development of the Regional Plan.

2. Officers can develop stakeholder engagement skills outside of the Navy, in the community.

3. Officers develop research skills with other agencies, educational institutions and stakeholder organizations.

4. The Plan provides the Navy and DOD with information of other ocean uses—Services can use this data in siting training, natural resource permitting, selecting new training areas and encroachment.

5. The Plan provides visibility (unclassified) of DOD training and testing areas to other ocean users so that they can site their activities with reduced conflict. (Griffin 2015)

The PIRPB plans to create decision support tools to streamline the processes involved in planning and managing ocean use and to reduce ocean use conflicts. U.S. Marine Corps Forces Pacific (MARFORPAC) is one of the federal representatives on the PIRPB and has partnered with the Naval Postgraduate School (NPS) to facilitate the development of decision support tools for the Pacific Islands CMSP effort. The research described in this thesis was conducted as part of the MARFORPAC – NPS endeavor and was intended to help generate an initial list of recommended requirements to be used in guiding the development of decision support tools. These requirements were developed by applying systems engineering methods to examine the process by which marine aquaculture companies attempt to obtain the permits needed for aquaculture operations. A sociotechnical systems analysis approach was used that started with a series of interviews of representatives of marine aquaculture companies to generate data for analysis. The data was then consolidated and refined by means of a content analysis.

From there, a functional flow block diagram (FFBD) was constructed to demonstrate the unit operations of the company as it proceeds through the permitting process. This diagram was decomposed to view the details of the process. A role network was also created to identify the interactions that occur between the aquaculture companies, government agencies, other organizations, and the public during the permitting process.

The content analysis, FFBD decomposition, and role network led to identification of the variances, or "unexpected or unwanted deviation(s) from standard operating conditions, specifications or norms" (Emery and Trist 1978) inherent in the permitting process and their potential effects on an aquaculture company. These variances were then analyzed to identify the key variances that could be mitigated to increase the efficiency of, or otherwise improve, the permitting process.

From these analysis results, 16 recommendations were developed for the design of decision support tools for coastal marine spatial planning (CMSP). These requirements were developed to align with the high-level CMSP functions and potential benefits to stakeholders that were identified by the PIRPB. These requirements are intended to be used to guide the creation of a decision support tool.

As an example, one of the key variances was found to be the response and review time of the various state and federal agencies in the Environmental Assessment process. One recommended requirement to address this variance was to design a permitting paperwork central hub capability into the decision support tool. The aim of such a capability is to allow agencies to communicate with both the company and among themselves to facilitate faster and more transparent discourse.

This thesis does of course have inherent limitations. The scope of the research was limited to the perspective of the marine aquaculture companies in Hawaii and thus does not provide the complete picture. Future research would benefit from a similar analysis from the government perspective. Additionally, future research could include studying companies in other industries such as tourism, mineral mining, and alternative energy. The systems engineering approach used in this study should be useful in addressing other aspects of coastal marine spatial planning, especially the development of decision support tools for other ocean activities that require permitting by government agencies.

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I. INTRODUCTION

Humans consider the oceans one of the greatest natural resources on Earth. Some have argued that the oceans are a misused resource. Jacques Cousteau is often credited as having said, “water and air, the two essential fluids on which all life depends have become global garbage cans” (Deodhar 2009, 379).

Humanity has made use of the oceans as far back as humans have walked the Earth. Increases in global population, technology, and wealth have caused an increasing demand for ocean resources. Modern man desires to use the oceans for such endeavors as commercial fishing, recreational fishing, tourism, energy generation, transportation, recreation, military training, mining, drilling, and farming. These diverse activities often overlap each other in space and in time. For example, ocean farming and military operations such as submarine training may require use of overlapping ocean regions. Given the wide range of ocean activities, they all have one major and inescapable commonality: geographical space.

These activities require square footage, or area, for execution. Complicating performance of some of these activities is that some take place in the depth of the ocean. Military operations such as submarine training, or ocean farming both require a three dimensional use of the ocean. These operations often require hundreds of feet of ocean depth in addition to the surface area footprint. Increasingly, in U.S. ocean waters, and around the world, these activities find themselves in conflict with one another.

Historically, land use spatial planning has been common and generally effective, but ocean spatial planning was rarely comprehensively or methodically carried out (Douvere 2008).

Involved entities have recognized the need to manage the coastal environment has, and various ad-hoc or incomplete measures have been put into place in recent decades (Douvere 2008). Local groups have allocated or managed the ocean spaces for some time. These efforts have been known by a variety of names including zoning, spatial planning, ocean zoning, and more. Recently, the federal government recognized the need for a more comprehensive plan.

On June 12, 2009, President Obama ordered the heads of executive departments and federal agencies to establish an Interagency Ocean Policy Task Force (Griffin 2015). He directed this task force to develop recommendations to improve America's stewardship of the oceans, coastal areas, and the Great Lakes. The task force produced a set of Final Recommendations for ocean stewardship. The president implemented the recommendations by issuing Executive Order 13547 on July 19, 2010. The Executive Order states, among other things, that executive departments, agencies, and offices shall "participate in the process for coastal and marine spatial planning." Executive Order 13547 also states that:

> This order also provides for the development of coastal and marine spatial plans that build upon and improve existing Federal, State, tribal, local, and regional decision making and planning processes. These regional plans will enable a more integrated, comprehensive, ecosystem-based, flexible, and proactive approach to planning and managing sustainable multiple uses across sectors and improve the conservation of the ocean, our coasts, and the Great Lakes. (Exec. Order No. 13547, 1)

This order covers many ocean uses, including ocean farming, known more commonly as marine aquaculture. In fact, marine aquaculture offers an excellent subject for a study of the difficulties of managing competing ocean use interests among private, public, and military entities. This is due to the fact that aquaculture companies are privately owned and managed but must adhere to numerous federal and state regulations.

After the Executive Order was signed, Marine Corps Forces Pacific (MARFORPAC) was tasked with leading the Pacific Islands Regional Planning Body (PIRPB; Pacific Islands RPB n.d.) and its associated coastal marine spatial planning (CMSP) efforts. The Naval Postgraduate School (NPS) has undertaken the task of assisting the PIRPB in the CMSP effort. Specifically, there is a project underway, of which this work is a part, to develop a CMSP decision-support system. One of the three project deliverables involves the development of a decision support and management tool for use by the PIRPB (Murphree and Guest 2015). It was in support of this decision tool that all further research and analysis for this thesis was conducted.

This thesis focused specifically on the Hawaiian Islands. Historians surmise that the population of native Hawaiians was once within the range of 200,000 to over 1,000,000 (Dye 1994). Hawaiians used the ocean for various things such as fishing, fish farming, and surfing (Nendel 2009). They developed cultural rules or laws, known as *kapu*, to regulate the spatial and seasonal use of the oceans. In fact, certain areas of the oceans were off limits to fishing during certain parts of the year (Kamakau 1992). These ancient cultural rules demonstrate that spatial planning was important centuries ago. This is still true today and is a key factor in ocean spatial planning in this region of the world.

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II. LITERATURE REVIEW

A. AQUACULTURE PLANNING AND PERMITTING DIFFICULTIES

Of all the ocean uses discussed earlier, one could argue that aquaculture and alternative energy face the greatest challenges obtaining approval and use of a particular ocean space. These are innovative industries compared to more traditional ocean uses such as recreation, fishing, transportation, and military activity. As such, both industries bear careful analysis when considering the implementation of Executive Order 13547. This section discusses aquaculture planning and permitting, being the focus of this thesis, is further discussed in this section.

Perhaps, however, "permitting" is too simple a term to use. Permits are required and are a critical part of spatial planning, to be sure, but obtaining approval to conduct ocean-farming operations involves a much more laborious undertaking than the word "permitting" might otherwise imply. In pursuing the goal of developing a comprehensive marine spatial plan, one might ask what permits are required and why they are required in the first place.

Kelly Robinson, an economist and professor at Rutgers University, wrote on the topic of environmental permitting and noted that

> permitting is inherently complex, because regulators must match control methods and operational requirements to the specific technological characteristics of the firms they regulate. Permit activities also tend to be fragmented, because most environmental agencies are organized according to "media divisions" corresponding to air, water, solid waste, and so forth, each with its own permits. This complexity and fragmentation in environmental permitting imposes direct costs on firms. (Robinson 1999, 246)

These direct costs include research to determine what permits are needed and how to obtain them and to analyze various environmental compliance alternatives within the context of the organizational norms, file documents, track and update permit applications, and maintain permits as required after approval.

Additionally, organizations may incur indirect costs from the permitting process. These indirect costs can include prolonged delay of production and general business uncertainty (Robinson 1999). These indirect costs deter investors and make financing more difficult to obtain.

The difficulties and costs involved in permitting may lead to four unintended and negative consequences for the organization seeking a permit (Robinson 1999). First, if an organization faces high permitting costs, they may be more likely to skirt the actual regulations and operate without certain required permits. This tendency may be further exacerbated if the organization perceives that enforcement is low or non-existent. Second, if like most government agencies, the permitting agency experiences budgetary constraints, they may have inadequate resources both for issuing permits and for conducting monitoring and enforcement of them. Third, the previously described "media division" permitting system can lead to pollution that goes unaccounted for when operation actually begins due to the permit holder shifting pollution accountability from one medium to another (Anderson and Herb 1992). Lastly, some organizations may be able to "game an agency by seeking out the division that gives them the most favorable rule interpretations" in an effort to obtain permits more quickly (Glick 1996).

These factors underscore the importance of CMSP. It may prove difficult to properly manage or zone the oceans without a clear permitting process that undergirds the zoning. The good intentions behind a spatial plan may suffer if users of the ocean (for example, the military, aquaculture companies, alternative energy companies, fishers) are stymied by an inefficient permitting process. Several case studies, described in the next several paragraphs, provide insights into the difficulties of obtaining permits, and the need for effective spatial plans. These studies indicate that, in many cases, spatial planning seems to have evolved in a more or less piecemeal manner rather than by specific design. Comprehensive CMSP is important in enabling an efficient planning and managing process for all involved also persons and organizations. These persons and organizations are also known as stakeholders.

Scallops are an important natural resource in many places. But, like so many of the ocean's natural resources, the scallop population is declining in most of the world

(Goudey 1996). However, Japan has overcome this problem, and in fact eased or largely eliminated pressure on wild scallops by farming scallops in a comprehensive and planned way. In 1996 there were over 1900 scallop-raising operations in a single region of Japan, Mutsu Bay. Goudey (1996) found that the farmed scallops provide a stable harvest at a reliable price and leave the population of wild scallops relatively unscathed. This is done with a minimal impact to the environment while also taking into account competing ocean uses.

In 1996, the Westport Scallop Project attempted to replicate the success of the Japanese farmed scallop industry (Goudey 1996). This project provides a case study in the complexity of marine aquaculture planning and permitting. The Westport Scallop Project, composed of a group of scallop industry and scientific interests, set about trying to evaluate several methods of growing juvenile scallops, known as spat, in open ocean waters off the coast of Massachusetts. One method involved rearing the young scallops in cages on the ocean floor, while another used suspended cages that were four meters tall. The varied approaches to raising scallops required both ocean area and depth, which added complexities to the related spatial planning. Site selection was extremely important to the effort. Many factors, not the least of which included logistics and environmental conditions, greatly influenced the selection of the scallop farm location. Logistics was a concern due to the time and expense incurred for sites far from the project home at Woods Hole, Massachusetts. Environmental conditions were important due to the specific temperature, salinity, tidal flow, and natural planktonic food sources that scallops require to survive. Additional constraints included the consideration of fishing activity and other maritime interests, such as shipping and military exercises.

The proposed site was in federal waters. No fewer than eight federal agencies were involved in the permitting process for this site, including the U.S. Army Corps of Engineers, the U.S. National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the U.S. Coast Guard, the Department of Defense, the Department of State, and the Department of Interior. The site approval process took over three years and involved relocating the proposed site. The author of the case study article noted that “the tortuous path of this project toward site access is evidence of the lack of a rational approval process” (Goudey 1996, 25).

A more recent study from 2014 supported the findings of Goudey (1996). In fact, the 2014 study by Boden and Mignone states that “the historic absence of proposed projects in federal waters has largely been a result of the complex and difficult federal permitting process” (Boden and Mignone, 2014). Modern aquaculture organizations must still navigate a plethora of federal permits in order to obtain rights to a specific area of ocean and conduct operations in federal waters.

Two prospective aquaculture organizations have sought to obtain permits to conduct mussel farming, once again off the coast of Massachusetts. They have had to pilot their way through the following process.

The Rivers and Harbors Act (RHA) grants the U.S. Army Corps of Engineers the authority to issue permits for activities that block or obstruct “the navigable capacity of any of the waters of the United States” (Rivers and Harbors Appropriation Act of 1899). The National Marine Fisheries Services (NMFS) has authority, under the Magnuson-Stevens Fishery Conservation and Management Act, to determine if a proposed site is detrimental to a protected aquatic species (Boden and Mignone 2014). The Environmental Protection Agency (EPA) may become involved due to the Clean Water Act (CWA), which governs the discharge of pollutants in the navigable waters of the United States. The Coast Guard also requires a permit for the maintenance of any aids to navigation that may be required. Additionally, the permitting may require consideration under the National Historic Preservation Act. Finally, under the Coastal Zone Management Act, a second neighboring state can effectively override a neighboring state’s permitting process if a proposed operation is deemed to be inconsistent with the second state’s coastal zone management plan.

The previous case studies involved only federal waters. When aquaculture interests propose to farm in the coastal waters of a state, the permitting process grows ever more tortuous due to layered federal, state, and local agencies. Some states have tried to assist in navigating the permitting process.

In order to combat all of the concerns, fragmentations, and shortcomings of the permitting process, many states have developed a single office that functions as a consolidator for many types of permitting, including ocean use permitting. In fact, a study by Robinson (1999) found that 44 states had such consolidation programs in place, although their construct varied widely from state to state (Robinson 1999). The study administered a survey to the workers of these programs and found that almost all of the state permitting consolidation offices: (a) were mainly disseminators of information; and (b) performed little to no actual assistance with permitting, interagency coordination, or compliance. They also performed their services "on a highly discretionary basis" (Robinson 1999, 248) and so organizations seeking a permit could not rely on the assistance of these offices.

These prior studies indicate that aquaculture permitting is a difficult process but also necessary. The permits are intended to ensure the safety of the environment, the proper use of the ocean waters, the preservation of historic or sacred sites, and the safe navigation of America's waters. Each of these factors inform the spatial planning of the ocean due to their influence on the siting of an aquaculture operation.

The aquaculture permitting can be thought of as a system. The permitting process receives inputs, performs functions related to permit approval, and creates an output in the form of either permits or rejected permit requests, similar to the transformational process described by Taylor and Felton (1993), Blanchard and Fabrycky (2006), and numerous others in the field of systems engineering. Therefore, the permitting process be analyzed from a systems perspective—in particular, analyzed as a sociotechnical system. The system contains interactions between agencies in a process utilizing people and technology; thus, the system is a sociotechnical system similar to the type described by Taylor and Felton (1993).

B. AQUACULTURE PERMITTING FROM A SYSTEMS PERSPECTIVE

Careful review of the literature mentioned in the previous section shows that past efforts to construct a permitting process for aquaculture generally lack a systems engineering approach. Failure to consider this type of approach to building the process may have contributed to the complexity, expense, and difficulty in obtaining permits.

Systems engineering attempts to look at all components or parts of a system holistically in order to determine a solution to a problem (Blanchard and Fabrycky, 2006). This of course begs the question of what exactly is a system. There are many relevant definitions, but one notable source says that "a system is an assemblage or combination of functionally related elements or parts forming a unitary whole, such as a river system or a transportation system" (Blanchard and Fabrycky 2006). These authors go on to say that a system, and specifically an engineered system, is made up of three primary pieces including components, attributes, and relationships. Components represent the parts of a system. Attributes are the properties of both the components and the whole system. Relationships describe the interactions of the components such that they operate in harmony toward the accomplishment of the system's purpose.

As previously discussed, the aquaculture permitting process may be considered as a system. The components of this system are the agencies and organizations involved in the process. The attributes are the "characteristics, configuration, qualities, powers, constraints, and state" of those agencies and organizations (Blanchard and Fabrycky 2006). These components must interact on numerous levels that are explored in subsequent analysis. Review of the subject literature cited earlier in this section has shown that the agencies involved in permitting do not necessarily operate in harmony toward the accomplishment of permitting. Thus, a systems engineering approach seems an appropriate method of trying to improve the process by which an aquaculture company can obtain a permit to use an area in accordance with a coastal marine spatial plan.

One such method that has a history and is established as a robust tool in the field of sociotechnical systems (STS) analysis is known as macroergonomics (ME). One early reference that describes the concept of sociotechnical systems is Cooper and Foster in 1971. They describe a sociotechnical system as a production system that requires both technology and "a work-relationship structure that relates the human operators both to the technology and each other" (Cooper and Foster 1971). They also argue that an organization, such as a company, ought to be viewed within the proper context and that "current perspectives view organizations as dynamic complex structures in symbiotic relationship with their environments" (Cooper and Foster 1971). Put another way, one might say that "at its core, STS provides the perspective that a system is inextricably affected by its environment and that there are several sub-systems involved in effective work system design and redesign" (Kleiner 2006). The word "environment," in this context refers to that which occurs outside of the bounds of the organization but still affects the organization.

Brian Kleiner is a well-known expert in the field of macroergonomics and STS. He defines macroergonomics as "the design of work systems which focuses on organization-system interaction" (Kleiner 2006). In other words, ME looks closely at how an organization operates within the context of the system in which it exists. One method of analyzing and designing a work system is through a methodology known as MacroErgonomic Analysis and Design (MEAD) (Kleiner 2002). Kleiner defines a work system as "one that involves two or more persons interacting with some form of (1) hardware and/or software, (2) internal environment, (3) external environment, and (4) an organizational design" (Kleiner 2002, 1). An important note concerns the difference between the internal and external environments. The internal environment is made up of physical parameters including, but not limited to, light levels, sound, quality of the air, and temperature. The external environment is the elements that the organization must relate and respond to in order to achieve success. These could include political influences, government agencies, socioeconomics, local and national culture, media attention, available employees in the labor market, or financing opportunities. Finally, the organizational design of the work system is comprised of the organizational structure and the processes that the organization undertakes to accomplish the various tasks and functions that fulfill its intended purpose (Kleiner 2002).

Macroergonomics, and MEAD by extension, seeks to first understand and then design or re-design a system such that the optimal organization-system interaction is achieved. Often, work systems suffer from certain shortcomings driven by one of three primary problems. They are 1) technology-driven design, 2) a leftover approach to design, and 3) inattention to the sociotechnical characteristics of work systems (Kleiner 2006). While computing, information, and communication technology continues toward greater and greater feats of accomplishment, the prevalence of these three problems, or pitfalls, does not appear to have been reduced (Kleiner 2006). Rather, that march toward greater technology appears to have exacerbated the problem, as technology leaps ahead of work system design in certain industries.

Now that STS and macroergonomics has been defined and introduced, the actual implementation of the MEAD methodology bears discussion. MEAD is characterized by 10 discrete steps. A list of these steps is shown in Table 1.

Table 1. MEAD 10-Step Methodology. Source: Kleiner (2006).

1. Scanning the environmental and organizational design sub-system
2. Defining production system type and setting performance expectations
3. Defining unit operations and work process
4. Identifying variances
5. Creating the variance matrix
6. Creating the key variance control table and role network
7. Performing function allocation and joint design
8. Understanding roles and responsibilities perceptions
9. Designing/redesigning support sub-systems and interfaces
10. Implementing, iterating and improving

MEAD begins with a scan of the environmental and organizational design sub-system. The scan endeavors to identify the organizational boundaries and subsequent environment in which they occur. Step two requires defining the production system type and setting performance expectations. In this step, one will identify key performance criteria and drivers, and make use of subjective measures, such as self-reports, and objective measures. The value in defining the production system type lies in the ability to better determine the optimal levels of complexity, centralization, and formalization (Kleiner 2002), as well in assessing the efficiency, effectiveness, productivity, quality, quality of work life, innovation, profitability or budgetability (Sink and Tuttle 1989) and flexibility (Kleiner 1997) of the organization.

The third step is to define unit operations, or transformational steps, and work process. The objective of this step is to permit the analyst to identify the units or grouping of conversion steps required to complete the work process. The fourth step is to identify variances. Some define variances as "unexpected or unwanted deviation from standard operating conditions, specifications or norms" (Emery and Trist 1978). Another definition states that variances ought to be considered "not as problems to be solved, but as deviations around a norm, or average. Incorrectly applied the variance concept is often characterized as 'problems'" (Taylor and Felten, 1993). Regardless of the definition used, variances represent a deviation from the desired state of the process and can have significant consequences on the organization's process flow. Thus, the objective of variance identification is gain a robust understanding of the possible unexpected and unwanted deviations from the desired or expected work process.

Fifth, a variance matrix is created. This matrix lays out the key variances in the process in a methodical and logical manner, which facilitates identification of the key variances (Taylor and Felten 1993). These key variances are key because they are those that cause the greatest perturbations to the process and thus generate the most severe schedule delays and cost increases. Such identification can allow the ergonomist to better understand how to control the variance in subsequent re-design, which is something that occurs in the next step.

Step six is to create a key variance control table and role network. This is used to determine how existing variances are controlled or mitigated by the organization. A job may be defined by a formal job description that encompasses the agreed upon tasks that an employee will accomplish within an organization. A role, on the other hand, "comprises the behaviors of a person occupying a position or job in relation to the other people" (Kleiner 2006). Others describe role networks as a "focal role network," or a "mapping of relationships indicating who communicates" with the focal person within an organization (Taylor and Felten 1993). They go on to declare that a proper role network exhibits spacing between various people to indicate the frequency and intimacy of interaction. For instance, a person who is in nearly constant communication with the person in the focal role should be placed close to the focal role person in the network diagram. In contrast, someone who rarely interacts should be placed far away. Finally, people with no direct interaction might receive inclusion in the diagram but may not have an arrow drawn between them and the focal role person.

Step seven is to perform function allocation and joint design. This involves allocating functions and tasks to both humans and machines such that allocations are made appropriately and do not infringe on political, cultural, financial, or other considerations demanded by the environment. Additionally the analyst evaluates how design changes to the technology and personnel sub-systems might benefit the organization.

Step eight is to understand roles and responsibilities perceptions. This step aims to identify how workers perceive their roles by making use of the previously constructed tables and role network. The understanding gained can support further redesign of the work system in the next step.

The ninth step is to design or redesign support sub-system and interfaces. In this step, the analyst must determine if other organizational subsystems require redesign or must have an original design to better support the work system. Finally, step ten involves implementing the organizational redesign.

Figure 1 is a graphical representation of the general MEAD methodology (Kleiner 2006) and gives a visual representation of the analysis method used in this study. The figure shows the steps outlined above as a flow chart. It also shows how each step informs the other and reaches back to help develop a complete understanding of the system and how it operates.

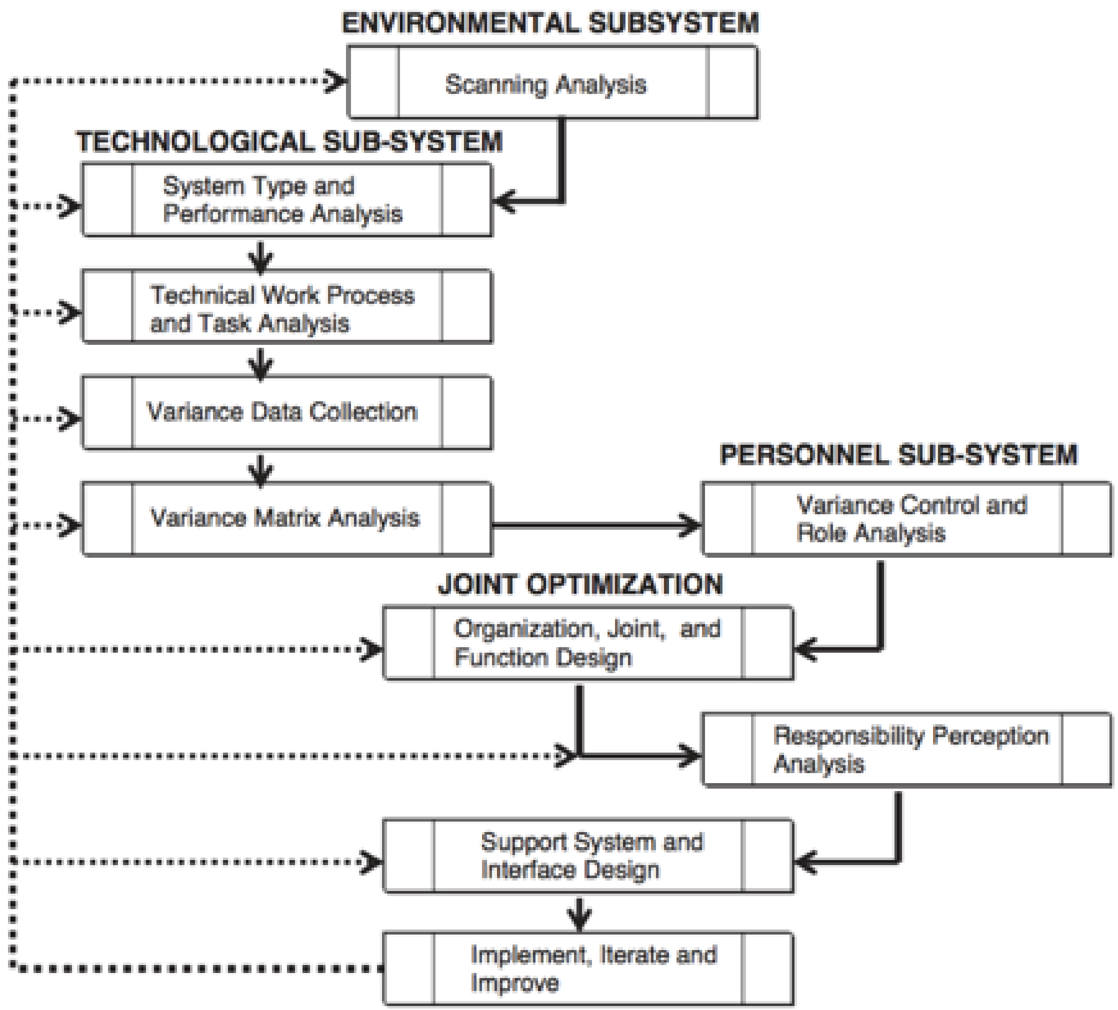

Figure 1. Graphical Representation of MEAD. Source: Kleiner (2006).

C. REVIEW OF PREVIOUS ME/STS STUDIES

MEAD has been used in numerous applications. For example, a modified macroergonomic approach was used to analyze how to improve the waste management system in Jakarta, Indonesia. Certainly, such a task is a daunting one but also one that could provide a deeper understanding of how effective MEAD might be in another industry.

The study first defined the design framework of the system's environment and organization by modeling the waste management process (Suzianti et al. 2013). This model, while simple, provided a clear understanding of the inputs, process, and outputs of the system and its environment. Next, they conducted step two of MEAD: defining system type and setting performance expectations. In doing this, the authors identified problems in six areas that pertained to the prescribed areas of efficiency, effectiveness, productivity, quality, quality of work life, innovation, budgetability (Sink and Tuttle 1989), and flexibility (Kleiner 1997) of the organization. These included problems in the transportation facilities, human resources, total waste collected, budget, citizen participation, and law enforcement (Suzianti et al. 2013).

Then, the study defined unit operations in accordance with the third step of MEAD and created a detailed process model. This process model provided a simple visual that made a seemingly complex and amorphous waste management system more approachable and understandable. Next, the authors followed the MEAD step of identifying variances and creating a matrix of these variances. Then the authors were able to propose methods for controlling the key variances.

At this point, the study was truncated and combined the final six steps of the ten-step MEAD method. Feeling that the key variances had been identified, the authors sought to redesign the part of the process that was responsible. In doing this, they kept in mind the roles various workers and participants in the system fulfilled. The methodology was effective at generating a possible solution to the waste management problem in Jakarta. This study shows that the methodology is relatively straightforward and can be adapted for specific systems. The study also demonstrated that the methodology may be malleable enough to facilitate modifying the approach where appropriate.

Another study used a sociotechnical systems analysis approach to look at the integration of computer kiosks into four hospital emergency rooms. These kiosks were intended to aid patient check-in and triage. The study used an ME approach to analyze the importance of roles within the system. Specifically, the study determined that despite their job descriptions, the nurses' actual roles included aiding with the use of the kiosks (Ackerman et al. 2012). The study identified that the nurses, who ended up playing the main role in operating the kiosks, were not a part of the design process for the system. This seemed to lead to resistance on the part of the nurses toward the integration of the system. Identifying the roles that people play is a key consideration in the analysis and potential redesign of a system.

There were no prior studies found in which macroergonomics has been used to investigate aquaculture systems or other coastal or marine systems. But prior macroergonomic analyses of a wide range of other systems indicate that a macroergonomics approach to the aquaculture permitting process could provide useful insights for improving that process.

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III. METHODOLOGY

To study the marine aquaculture permitting process in support of CMSP, there is a need for data. The MEAD methodology certainly requires a variety of forms of data including data related to the organizational environment such as stakeholders and their desires. Necessary data also includes information on the tasks required to be performed in the pursuit of a permit. This author's attendance at numerous lectures on aquaculture at the World Aquaculture Society (WAS) 2016 Conference in Las Vegas, NV accompanied the initial baseline review of prior studies. These lectures indicated that the aquaculture planning and permitting process is not straightforward. Thus, it seemed prudent to interview those who have actually gone through the process of obtaining a permit to conduct open ocean aquaculture in Hawaii. This thesis used these interviews to provide provide the bulk of the data needed to understand the permitting process using the MEAD methodology.

A. RECRUITMENT

The process of conducting interviews involves gaining permission from the Naval Postgraduate School (NPS) Institutional Review Board (IRB) to conduct human subjects research. A standard human subjects research package, submitted to the board, provided the elements necessary for IRB review. This package contained the interview questions, informed consent forms, a recruitment protocol, and documentation of necessary IRB human subjects research training. The approved IRB package included a recruitment protocol that was used as a standardized way of contacting potential interview subjects. This protocol is included as Appendix A.

This study used two primary means to identify potential interview subjects. First, attendance at the WAS 2016 led to several contacts. Although no attempt at recruitment was made at the WAS, the contact information gained proved useful in recruitment subsequent to gaining IRB permission. Secondly, internet research provided an additional means of identifying potential interview subjects. Internet searches showed several potential companies along with basic contact information.

This contact-gathering led to the sending of nine emails using the IRB approved recruitment protocol. Three potential interview subjects provided positive responses.

B. INTERVIEW QUESTION FORMATION

Question formation was a critical pre-interview consideration. Appropriate questions are more likely to yield useful data that lends itself to MEAD analysis. The selected questions were based, in part, on results from the aforementioned journal articles on MEAD, STS, and macroergonomics as well as "Performance by Design" (Taylor and Felten 1993). These questions were also developed to account for the seven MEAD steps chosen for this study, which were steps 1–6, and 8. This thesis did not perform steps 7, 9, and 10 (function allocation, redesign, and implementation respectively) due to the nature of the project. As a research thesis, no opportunity existed to redesign and alter the process. The interview questions are shown in Appendix B. They are grouped into five general categories including general permitting scenario, organizational environment (with regard to obtaining a permit), detailed tasks, key factors, and process redesign. These categories and the detailed questions contained within aimed to elicit responses that facilitate exploration of the applicable steps of MEAD for data collection.

Question composition took into account the goal of completing the interview in 1 to 1.5 hours. The development of the questions tried to prompt an open-ended response to provide the interview subject the opportunity to include all relevant information rather than a short or terse reply. A danger of influencing the responses of the subjects existed if questions contained polarizing or leading questions. Therefore, question wording attempted to maintain a neutral stance to prevent undue influence in the responses. Guidance from the thesis advisor and the author's best judgment tried to develop questions in this spirit.

C. INTERVIEW PROCESS

The author recorded all interviews in order to obtain a complete transcript. Audio recording was used as it is simpler than video recording. Also, video recording seemed unnecessary in order to obtain the data needed. The recording device used was a Roland CD-2U. Standard 700 MB CD-R discs were used. Additional equipment, used in the transcription process, includes a Microsoft Windows-based laptop computer, Dragon dictation software, and basic headphones with integrated microphone.

Three interviews were conducted in Hawaii at the place of work of the recruited interview subjects. The interview subjects signed the IRB approved consent forms prior to any research questions being asked of them. Once the formalities of introductions and consent forms were completed, the recorder was turned on and the interview began. The researcher asked the questions directly from a copy of the IRB approved knowledge elicitation interview questions sheet. Subjects provided their responses and then follow-on questions were asked within the bounds of the IRB approved research package.

Two interviews ended earlier than the IRB mandated 1.5-hour time limit. One of the two ended early due to the subject having other obligations to attend to, and the second ended early due to the questions being answered in rapid fashion. The third interview took the entire 1.5 hours.

Each interview was recorded to its own CD. The CD was clearly labeled and dated in order to maintain order. The labeling was kept anonymous to protect the identity of the subjects.

D. TRANSCRIPTION

The recorded CDs were transcribed after all of the interviews were completed using Dragon Dictation Software from Nuance. Both the student researcher (LCDR Tyler McDonald) and the Primary Investigator (PI) (Dr. Karen Holness) reviewed the transcripts to identify and remove any personally identifiable information (PII). Anonymity was considered crucial due to being a promised part of the recruitment protocol. In accordance with IRB policy, the author and PI removed all PII from the transcripts as well as any portions of the interviews that could reasonably be thought to lead to identifying the interview subject or the involved company. This included individual names, job positions, company names, fish species, and unique equipment design descriptors.

E. INTERVIEW ANALYSIS

The transcript data contains answers to the questions that are mapped to specific steps of the MEAD methodology. The three interviews were analyzed using a technique known as content analysis. Content analysis provides a method of comparing and contrasting the responses from all participants in order to accurately summarize the responses and complete each MEAD step. Initially the intent was to analyze each question by going through all three interviews one question at a time. In other words, question one would be analyzed on all three interviews and then question two, and so forth. Analysis was to be done by using a clustering method to discern common themes, patterns, and functions in the permitting process.

"Clustering operationalizes something humans do most naturally: forming perceptual wholes from things that are connected, belong together, or have common meanings, while separating them from things whose relationships seem accidental or meaningless" (Krippendorff 2004). The goal of clustering is to group words, phrases, and concepts in such a way that one can deduce the system.

It quickly became apparent that the nature of the subjects' answers did not lend itself to a strict question-by-question clustering analysis. Thus, the clustering was done by performing a content analysis of the entire interview transcripts. This study used a top-down clustering method with the following general steps (Krippendorff 2004):

1. Search for key terms associated with high-level permitting activities.
2. Search for adjectives, lower-level activities, functions, and other factors that decompose the high-level permitting activities.
3. Continue the decomposition until there is nothing left to decompose.

The clustering method results were used to determine the functional flow block diagram (FFBD) and thus the unit operations of the aquaculture companies represented by the three interview subjects. This unit operations FFBD relates to unit operations step of the MEAD methodology.

Each of the unit operations were decomposed into their own detailed FFBD. Clustering also yielded insight into the role interactions that occurred in the pursuit of a marine aquaculture permit. The role interactions were also diagrammed. These role interactions showed the breadth of persons and agencies with which the primary permitting person at each company had to network with. Models were constructed for the unit operations, decomposed unit operations, and role network using CORE modeling software from Vitech Corporation and a Windows-based laptop computer. This software is particularly advantageous for systems engineering applications because it provides for traceability, requirements management, and development of system (or process) architecture. The unit operations and decomposed unit operations models were made using the FFBD option in CORE. Meanwhile, the role network was built using Lucid Chart, a freely available web-based diagramming software.

Finally, the content analysis yielded essential insight into the variances inherent in each step of the process. The transcripts were reviewed a final time in order to identify the variance associated with each of the unit operations. These variances were both directly stated or revealed during the course of the interview. As mentioned before, identifying variances is a key aspect in redesigning the system for improved operation. In the case of this study, identification of variances was intended to facilitate the formulation of recommended requirements for the marine aquaculture permitting and CMSP decision-support tools. A variance matrix was created using Microsoft Excel due to the ability to easily design a matrix style representation. From the variance matrix, key variances could be determined and mapped to the functions that they most affected.

F. REQUIREMENTS ANALYSIS

The INCOSE Systems Engineering Handbook states that "requirements are the foundation of the project," and that a requirements analysis must "identify and express verifiable requirements that state user needs in appropriate terms to guide system concept development" (Whalen et al. 2004). In the case of this project, the requirements are intended to contribute to the development of the permitting component of a decision-support system for CMSP. In order to gain confidence that the requirements generated by this project will meet the needs of the stakeholders, a requirements analysis must be done. A requirements analysis begins with problem definitions (Blanchard and Fabrycky 2006).

Then one must gain a thorough understanding of stakeholder needs and desires. This allows the analyst to define fully the capability requirements necessary to support an effective system. In the specific case of aquaculture companies, the process by which they obtain a permit is relatively unknown to the PIRPB, therefore, the needs that a decision-support system could support were not well understood. The STS analysis facilitated a needs analysis for aquaculture companies and the CMSP project.

The role network and key variances allowed for identification and generation of recommended requirements for the CMSP decision-support system software. A set of decision support tools is listed as one of the main objectives of the NPS CMSP project (Murphree and Guest 2015). Generating requirements to inform and support the design of these tools was the ultimate goal of this thesis research.

IV. DATA ANALYSIS RESULTS

A. CONTENT ANALYSIS

The clustering method of content analysis required thoroughly scanning the entirety of the interviews for all desired data. The interview questions were broken up into five separate categories to provide a clean flow to the interview. Content analysis of the five question categories yielded eight clustering categories that provided the data for further analysis. The raw data results are shown in Appendix C. Not all data was found to be relevant to the analysis and thus some of the aggregated data shown in the content analysis results was not used in subsequent work. The relationships between question category and content analysis output are shown in Table 2.

Table 2. Mapping of Question Category to Content Analysis Cluster

Question Category	**Content Analysis Cluster**
Permitting Scenario	Process
Environment	Stakeholders, Agency Desires, Variances
Detailed Tasks	Process, Timeline, Equipment Required, Roles Within the Company
Key Factors	Variances
Process Redesign	Variances, Redesign Suggestions

These relevant data were summarized into several basic content analysis clusters: process, stakeholders, agency desires, timeline, equipment required, roles within the company, variances, and redesign suggestions. Each cluster contains the specific data applicable to it. In the case of the process, these major sub-items were numbered based on their order of occurrence in the described process. In some instances, additional relevant data was listed under the major sub-items of each category. This content analysis provided the fundamental building blocks for all subsequent modeling, analysis, and requirements generation.

The process category provided the bulk of data needed to build FFBDs. The stakeholders clustering was used in the development of a role network. The timeline and agency desires clusters yielded insight into possible variances in the system. Equipment required clustering provided some additional insight into building detailed decomposed FFBDs. Roles within the company added to the role network. Lastly, the variances and redesign suggestions categories revealed data used in creating the variance matrix.

The list in Appendix C outlines the clustering done during the content analysis. It shows the clustering categories previously listed along with the data clustered within them. This list represents the author's attempt to summarize the perspectives of the interview subjects. The data contained in the list is shown for the reader's awareness and will be explained and explored in the subsequent sections of this thesis.

B. UNIT OPERATIONS AND FFBD

Using the interview transcript content analysis results, the FFBD shown in Figure 2 was constructed. It represents a high-level view of the author's understanding of all major functions related to obtaining a permit that must be completed by an aquaculture organization that desires to operate in the state of Hawaii. Each of the nine blocks in Figure 2 (1.1 – 1.9) represents a set of tasks that must be performed by a marine aquaculture company. Functions 1.2 through 1.8 are surrounded by a red box to highlight the functions that are most directly related to CMSP efforts, and for which CMSP changes could have the greatest impacts on both aquaculture companies and on the government agencies that are involved in the permitting process. For example, improvements in the interactions between the companies and the agencies could reduce the costs and shorten the timelines associated with the permitting process (see Chapter V, Section B for more discussion of potential improvements). The process described in Figure 2 appears to be very similar to the processes used in a range of industries that operate in the open ocean and near coastal environments, such as wind energy generation industry, and the oil, gas, and mineral extraction industries. Thus the results of our study may be applicable to the permitting processes used in other industries.

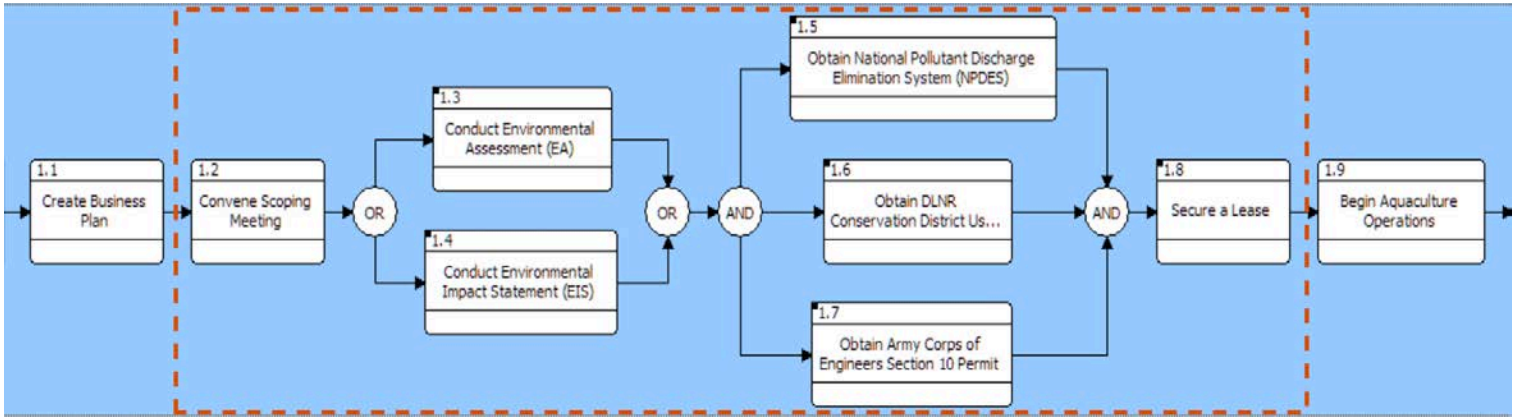

Figure 2. High-Level Permitting Process FFBD

Function 1.1 is “Create Business Plan.” This business plan represents the foundational first step toward acquiring an aquaculture permit. A business plan entails such considerations as budgeting, labor requirements, timelines, and logistics. In the formulation of such a business plan, a company must contemplate all of the other steps in the high-level FFBD, as well as their decomposed sub-steps. In doing so, the company strives to anticipate major hurdles and expenditures that would negatively affect their bottom line. Clearly, any of the variances that interview subjects identified in the content analysis have the potential to greatly affect the business, and are therefore items that the business plan may try to mitigate.

There are two major approaches that companies tend to take to deal with variances. They may conservatively plan for major variances in the process and build margin into their business plan. This requires a larger amount of capital and a longer timeline. Such a proposition can be discouraging to investors and prohibitive to startup businesses. The company may, on the other hand, choose to plan for a best case, or minimal variance process. In doing so, they may require fewer resources but also incur a greater risk of having inadequate resources to deal with obstacles to procurement of a permit.

Function 1.2 on the FFBD is “Convene Scoping Meeting.” To paraphrase one interview subject, the scoping meeting puts the state government on notice that a particular company plans to apply for an aquaculture permit. The company leadership works to gather as many relevant agencies together at the meeting in order to efficiently inform the agencies of the company’s intentions and get initial responses from the agencies.

At the scoping meeting, the company leadership lays out the vision for their company’s operations. This includes a brief on the basics of how they intend to conduct their aquaculture operation. The brief can include details such as intended location of operations, species of fish to be farmed, logistics, volume of production, and scale of operations. The brief also lays out the company plan for pursuing the permits necessary to begin operation.

Of particular interest, the company informs the scoping meeting attendees of their plan to pursue either a standard environmental assessment (EA) or the more rigorous environmental impact statement (EIS). It appears, based on the interviews conducted, that the environmental assessment is the preferred route for aquaculture companies in Hawaii. This may be due to its somewhat less rigorous requirements and apparent sufficiency for obtaining aquaculture permits. One company interviewed chose to pursue an EIS for reasons described in Chapter IV, Section C.

Functions 1.3 to 1.8 of the FFBD represent the core of the permitting process and represent the greatest challenges to the company. The tasks performed as part of these functions can be thought of as the steps that state and federal governments require of companies to ensure that operations conducted on or in the ocean are done in a safe manner and in ways that sufficiently protect the natural environment. These functions are discussed in detail in the following sections.

C. DETAILED DECOMPOSITION

Now that the high-level functional flow block diagram has been discussed, a detailed decomposition of high-level functions 1.3 – 1.8 will yield fruitful insight toward further analysis. The detailed decomposition seeks to break down each high-level function into its most basic sub-functions in order to realize fully how the high-level function is completed. In doing so, a picture of the variances inherent to the process begins to form.

1. Function 1.3, "Conduct Environmental Assessment" and Function 1.4, "Conduct Environmental Impact Statement"

Steps 1.3 and 1.4 on the FFBD are to "Conduct Environmental Assessment" or "Conduct Environmental Impact Statement" respectively. The company management must decide whether to pursue an EA or an EIS. This decision point is shown on the FFBD (Figure 2) by means of an "OR" node which indicates the availability of a choice between the two functions.

If the company management chooses to pursue function 1.3, “Conduct Environmental Assessment,” then they will need to prove to a number of state and federal agencies that their intended operations will not harm the environment. If this occurs, then the company will receive what is known in the industry as a finding of “No Significant Impact.” This finding is required to proceed with all the subsequent functions in the permitting process. In general, the EA function requires data gathering, modeling, report writing, public comments, agency review and feedback by the company, and finally a determination of the impact on the environment from the agencies.

An environmental assessment represents one of the more challenging paths that organizations are required to navigate in pursuit of a permit to conduct marine aquaculture operations. The decomposed EA process is shown in Figure 3. There are three basic stages to the EA process, including a stage comprised of data gathering, modeling, and report writing, a stage of taking and answering public comments, and a stage of interacting with various state and federal agencies. These stages are outlined on Figure 3. Figures 4–7 show enlarged portions of each of the three stages

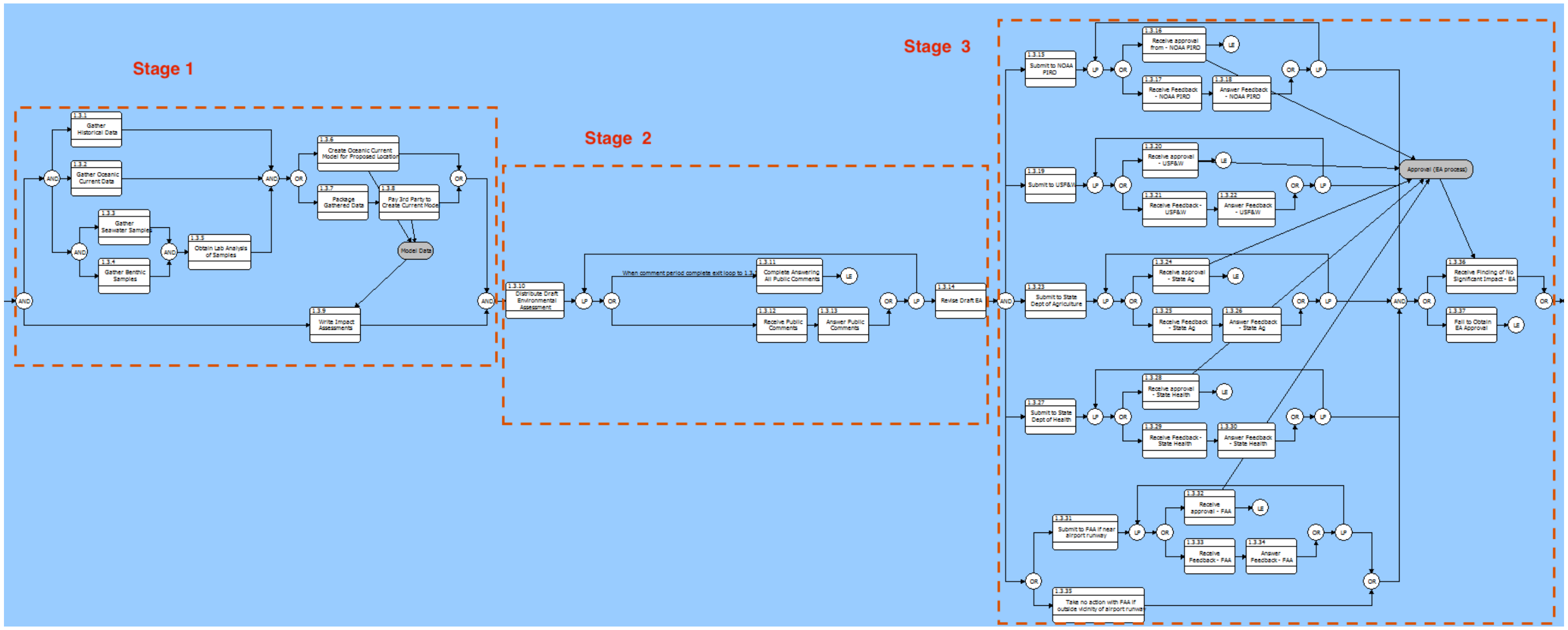

Figure 3. Function 1.3 Decomposition

a. Stage 1: Functions 1.3.1 – 1.3.9

The first stage begins with an “AND” node with two branches (Figure 4). The top branch leads to another “AND” node with three branches. These three branches show the company’s need to gather data on the ocean environment in the vicinity of the proposed site of operations. This data lays the foundation for writing the impact assessment and forming a reasoned and scientific approach to seeking a finding of no significant impact when the EA is reviewed by the various agencies

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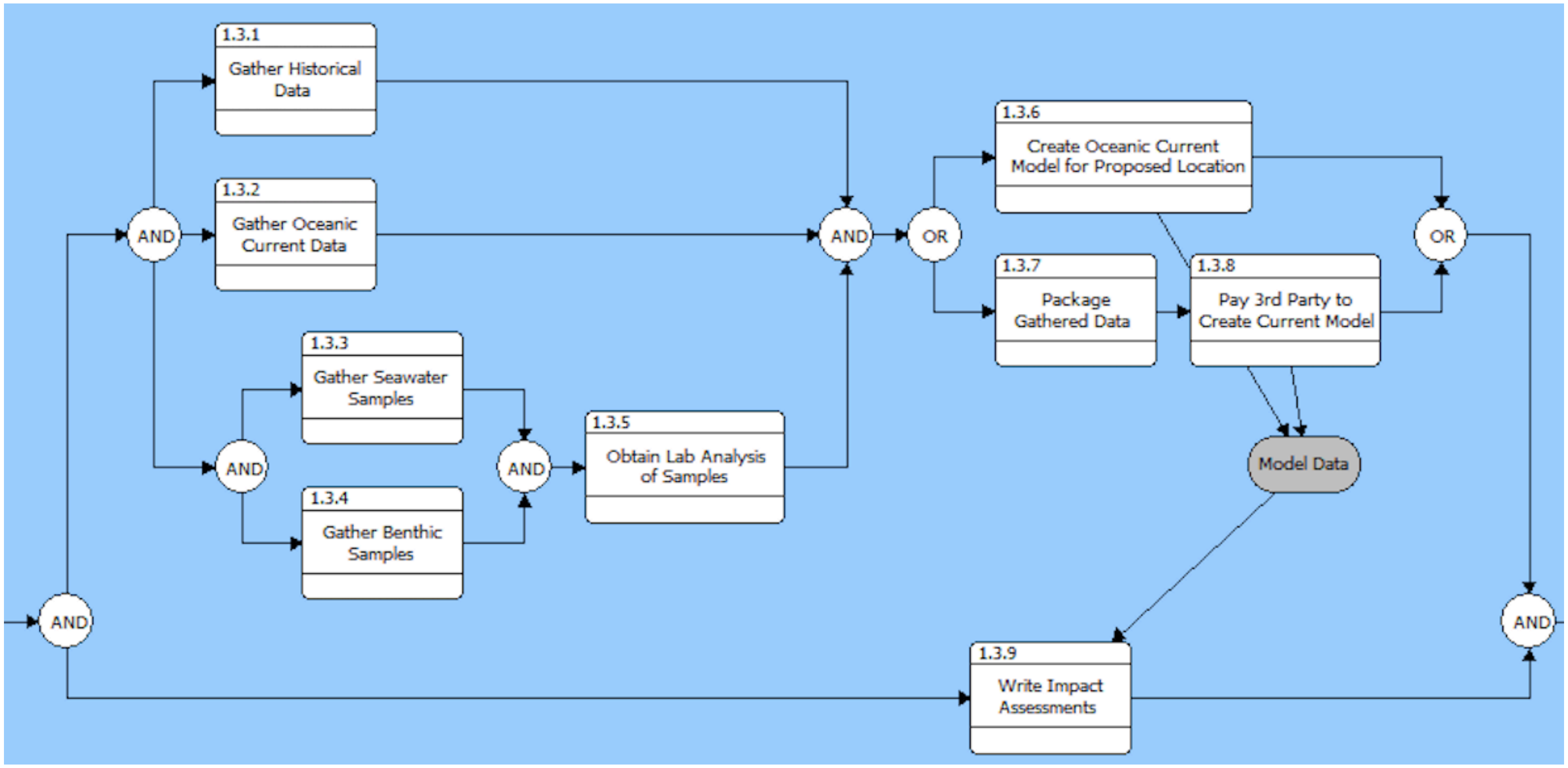


Figure 4. Conduct Environmental Assessment Stage 1

The first branch of the second "AND" node in Figure 4 is to function 1.3.1, "Gather Historical Data." This historical data includes things such as benthic habitat, historical ocean currents, tides, chemical analyses of seawater, bottom composition, and endemic species. This function was noted by one interview subject as being particularly problematic due in part to the lack of historical data in many of the areas that are appealing for aquaculture.

The second branch is to function 1.3.2, "Gather Oceanic Current Data" (Figure 4) This function addresses the company's need to provide accurate and recent data on the ocean currents in a particular area. Ocean current speed and direction are concerns for both regulators and the company. The company cares due to the potential effects of currents on both fish and equipment. Currents that are too strong can have an adverse impact on the ability of fish to thrive and grow. They can also damage or overly stress gear such as pens, tethers, and buoys. Regulators want to ensure that currents are sufficient in speed and direction to adequately disperse the waste that aquaculture operations, and especially the organisms being farmed, produce. Concentrated fish waste has the potential to negatively impact the environment by polluting a specific area, if the waste is not properly dispersed and diluted. Collecting ocean current information can be difficult for a company because, for example, it may require rental of expensive equipment and several months to gather a sufficient ocean current data set for data analysis.

The final branch of the second "AND" node in Figure 4 leads to another "AND" node. This node contains two branches to functions 1.3.3 "Gather Seawater Samples" and 1.3.4, "Gather Benthic Samples." Similar to function 1.3.2, these two functions involve taking samples of both the local seawater and the ocean bottom. After these two functions are complete, function 1.3.5, "Obtain Lab Analysis of Samples," may be completed. Most aquaculture companies send out their samples for lab analysis by a third party laboratory. This minimizes the amount of on-hand expertise they need and helps provide independent third party analyses.

After functions 1.3.1 to 1.3.5 are completed, the first "AND" node is exited and an "OR" node is entered (see the middle right portion of Figure 4). This node represents the company's need to produce an oceanic current model. The model takes into account all of the previously acquired data toward producing a product that models the way in which the predominant ocean currents at the proposed site will disperse fish waste and excess fish feed, and the probable effect on the chemistry of that area. This model will be used as part of the justification for a finding of no significant impact on the overall environmental assessment. Some companies do the modeling themselves, as shown in function 1.3.6, but most choose to execute functions 1.3.7 "Package Gathered Data" and "Pay 3rd Party to Create Current Model." Again, this third party work leverages independent expertise and eliminates the need for such expertise on the company's payroll.

Functions 1.3.6 and 1.3.8, in which creation of the oceanic current model occurs, provide an input to function 1.3.9, "Write Impact Assessment." The function involves writing the actual report on the expected environmental impacts that will be submitted to the agencies for review. This function is completed using simple computer word processing and spreadsheet programs such as Microsoft Office. The input, in the form of the actual oceanic current model, model outputs, and supporting data and documentation, are necessary before the impact assessment can be written.

b. Stage 2: 1.3.10 – 1.3.14

Once functions 1.3.1 through 1.3.9 are completed, the company enters the second general stage of conducting the EA, the public comment period (Figure 5). This is initialized when the company executes function 1.3.10, "Distribute Draft Environmental Assessment." In this function, the company must distribute hard copies of its draft EA to all state public libraries and newspaper outlets. This requires expenditure of resources to either hand deliver or mail copies of the draft EA to all of these locations. One interview subject stated that this required mailing copies of the EA to nearly 200 locations. The idea behind this requirement is that the public needs to have sufficient notice of a proposed aquaculture site, as well as access to the documentation that sums up the expected effect on the environment.

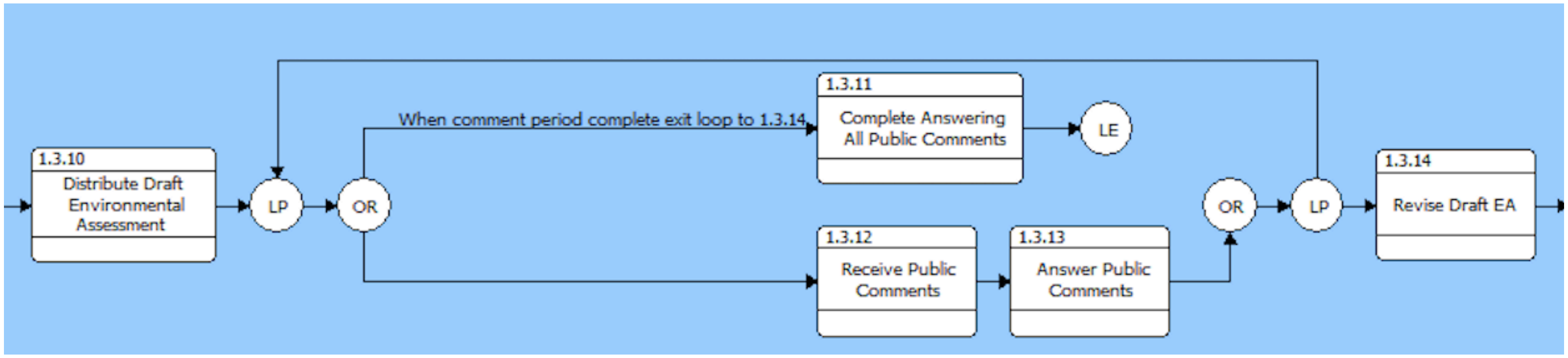


Figure 5. Conduct Environmental Assessment Stage 2

After function 1.3.10, an “LP” node is encountered which stands for “LOOP” (Figure 5). This “LOOP” node is frequently encountered both within the decompositions of function 1.3 as well as in numerous other decompositions. Thus, it will be described in detail here in order to provide a framework of understanding of the construct for future discussion.

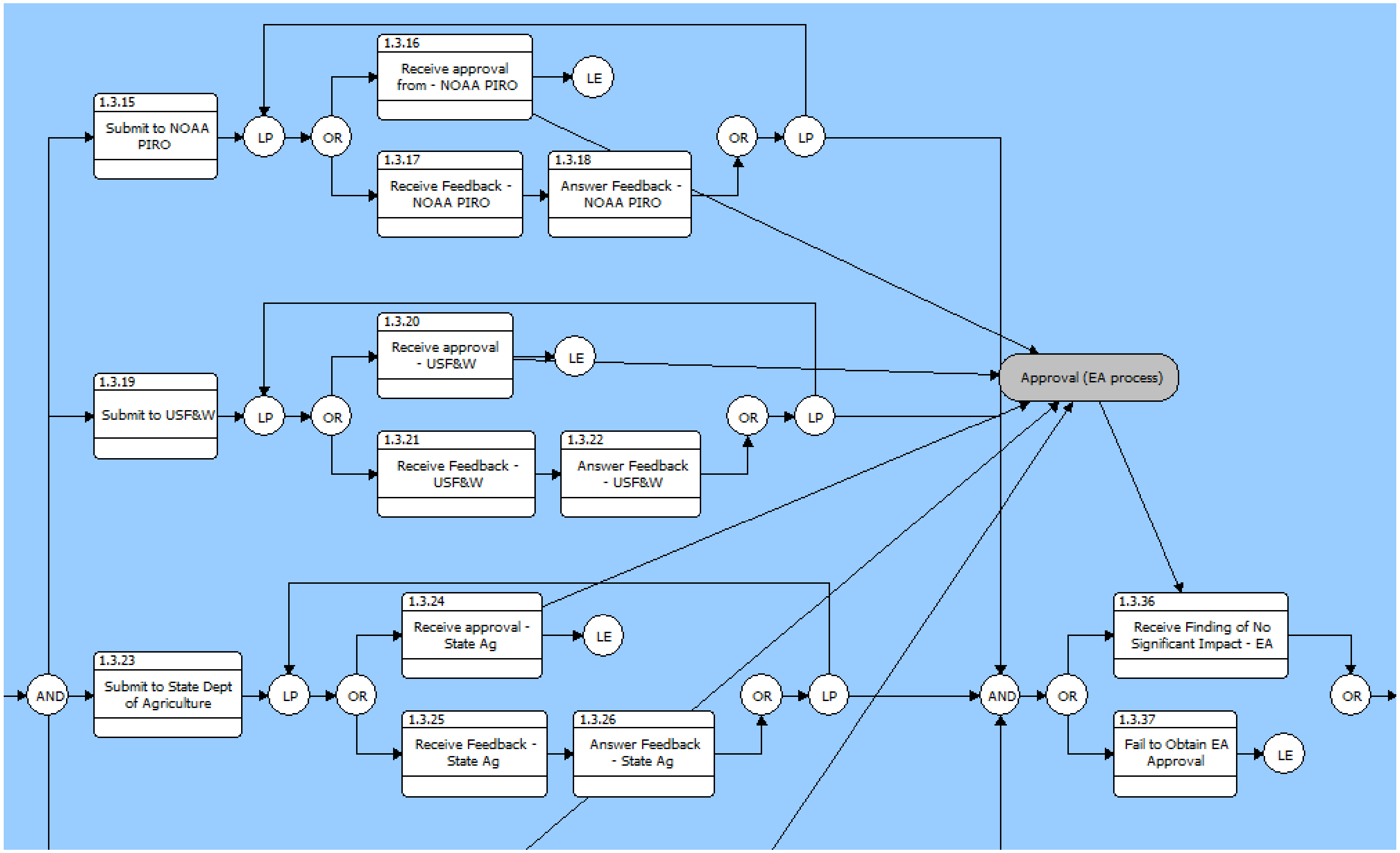
A “LOOP” node begins with an initial “OR” node, which leads to one of two conditional paths. For EA stage 2, the “LOOP” node leads to function 1.3.11, “Complete Answering All Public Comments” or to function 1.3.12, “Receive Public Comments” (Figure 5). Initially the company will wait to receive public comments and thus progress down the second, or bottom, branch of the “OR” node. When public comments are received, the company executes function 1.3.13, “Answer Public Comments.” After this function, the model loops back to the beginning of the “LOOP” node. When the public comment period is complete, the company is able to execute function 1.3.11 and exits the loop, by way of the “Loop Exit” (LE) to function 1.3.14.

In other words, the loop works something like the following. Once the draft EA distribution is complete, the public has an opportunity to provide comments, ask questions, and give feedback to the company. This can occur from individuals, social organizations, such as a fishing club, and non-governmental organizations (NGO), such as environmental or consumer protection groups. These people or organizations may raise their concerns as part of function 1.3.12. For example, an individual may voice concern that the proposed site of operations might negatively impact their view of the ocean. A fishing group might fear that their ability to traverse, fish, and generally use the proposed ocean site will be unduly restricted. Similarly, an NGO may state their worry that a farmed fish species might escape from the company fish pens and harmfully alter the gene pool of wild fish stocks. The company must then address these concerns in function 1.3.13. As an example, the company may respond to the individual that all equipment would be subsurface with the exception of a single buoy and therefore would not negatively impact the view. They may say to the fishing group that aquaculture pens normally have the effect of aggregating wild fish in the area and would thus have a positive impact on fishing. Finally, they might respond to the NGO by providing a detailed scientific argument for why the concern is either invalid or improbable.

Once the company executes function 1.3.11, “Completes Answering All Public Comments,” they move on to function 1.3.14, “Revise Draft EA” (Figure 5). The company revises the draft by incorporating all public comments into the appendix of their report. They may also edit the report to highlight their mitigation of public concerns. In some circumstances, they may substantially revise the report to address the questions and concerns that arose in response to the EA.

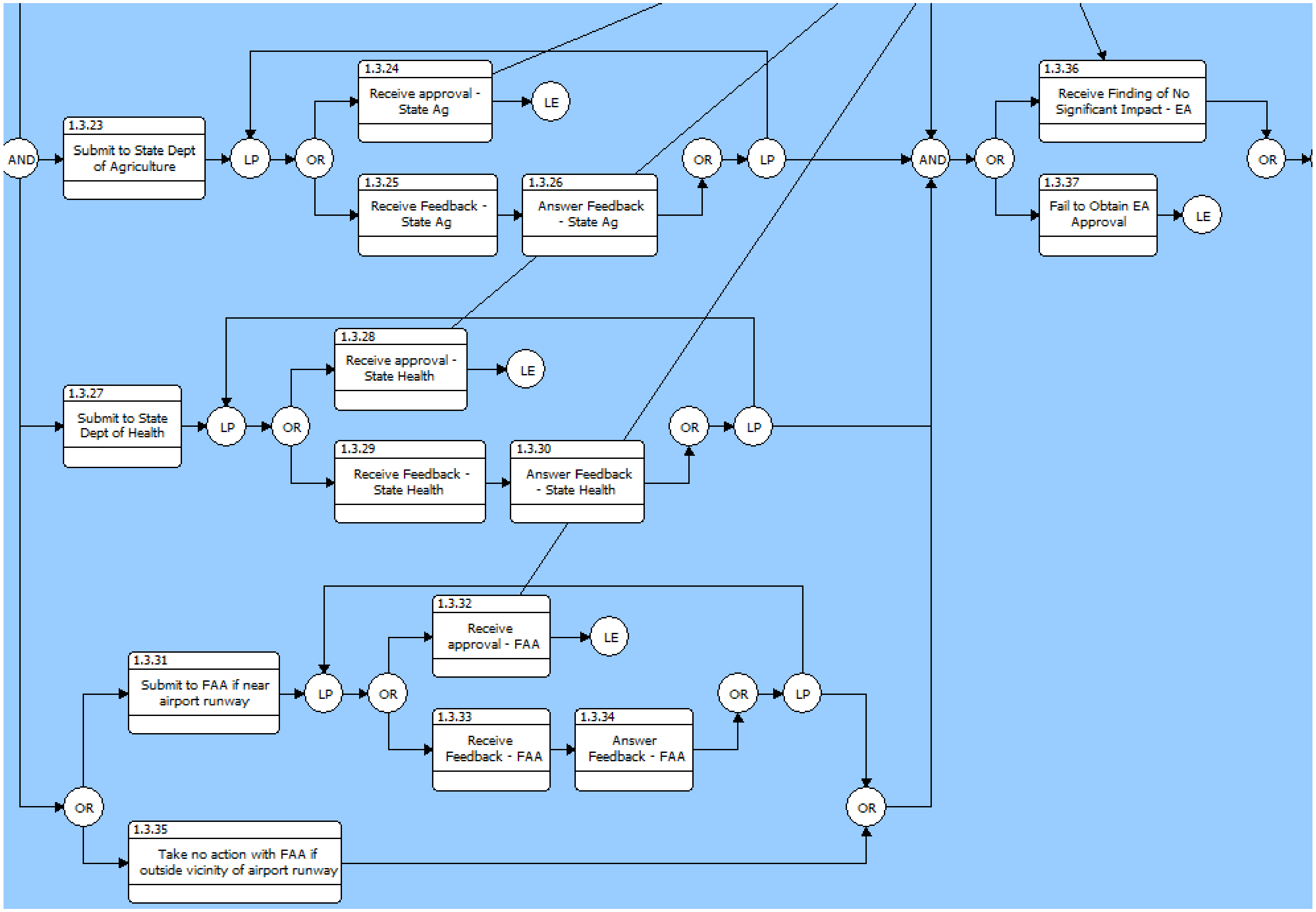
c. Stage 3: Functions 1.3.15 – 1.3.37

After completing function 1.3.14, the company enters the third and final stage of the decomposition of function 1.3 (Figures 6, 7). This stage involves submitting the revised EA report to the various state and federal agencies that have approval authority. This part of the process generally takes the most time and often results in the greatest frustrations for the company. The stage begins with an “AND” node with five branches. The first four branches are identical in construction. Each branch begins with submitting the revised EA to four different agencies. This is shown in functions 1.3.15, 1.3.19, 1.3.23, and 1.3.27 (Figures 6 and 7). These agencies are the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Pacific Island Regional Office (NOAA PIRO), the United States Fish and Wildlife Service (USF&W), the State of Hawaii Department of Agriculture, and the State of Hawaii Department of Health. Each of these four agencies has regulatory and review authority on the environmental assessment. The company must obtain a finding of no significant impact from each agency prior to the EA being approved by the agencies.



See Figure 7 for part 2.

Figure 6. Conduct Environmental Assessment Stage 3, Part 1



See Figure 6 for part 1.

Figure 7. Conduct Environmental Assessment Stage 3, Part 2

After submitting the EA to the various agencies, another “LOOP” construct occurs (Figures 6 and 7). This “LOOP” node is identical in construct to the one previously encountered in the public comment period in stage two. Thus, an “OR” node is encountered and the company initially either receives feedback from the relevant agency (functions 1.3.17, 1.3.21, 1.3.25, and 1.3.29) or receives approval of the EA. The interview subjects indicated that feedback is nearly always provided. Therefore, the company will follow the feedback with the function that answers the feedback (functions 1.3.18, 1.3.22, 1.3.26, and 1.3.30). After responding to the feedback, the model loops back to the beginning of the “OR” node. This continues until the agency is satisfied with the answers provided and decides to approve the EA. Once approval is received in functions 1.3.16, 1.3.20, 1.3.24, and 1.3.28, the loop construct is exited to the subsequent “AND” node (Figures 6 and 7).

This feedback loop works similarly to the one seen in the public comment loop, although the nature of the feedback tends to be more scientific and thus the responses to the feedback tends to be more rigorous. For example, NOAA PIRO may express concern over the potential impact of aquaculture operations to endangered species in the area. The company must then respond with how they will mitigate the concern or else argue that the concern is irrelevant.

Of particular note, one interview subject stated that one will not receive a disapproval from any of these agencies. Rather, the subject stated that the EA process would simply die. In other words, the agency will essentially shelve the EA and cease reviewing it. For this reason, the loop does not contain any sort of disapproval function; the idea being that a company will simply remain perpetually stuck in the relevant loop rather than receive an actual disapproval.

The fifth branch from the “AND” node contains a slightly more complex construct (Figure 7). The branch enters an “OR” node with two branches, the first being another submission function, function 1.3.31, “Submit to FAA if Near Airport Runway,” followed by the same loop construct (functions 1.3.32, 1.3.33, and 1.3.34). The second branch is to function 1.3.35 which states “Take no Action with FAA if Outside Vicinity of Airport Runway." Some aquaculture operations in Hawaii have congregated near the airport due to the appealing nature of the ocean waters in that area. In such a circumstance, the FAA must be consulted to ensure that proposed operations will not pose a safety or navigation hazard to air traffic.

Finally, the approval functions, functions 1.3.16, 1.3.20, 1.3.28, and 1.3.32, provide feedback to function 1.3.36, "Receive Finding of No Significant Impact," which is nested inside of an "OR" node (Figures 6 and 7). If all agencies concur that the proposed operation will not adversely harm the environment, then they approve the EA and a "Finding of No Significant Impact" is received. The second branch of this final "OR" node is to function 1.3.37 "Fail to Obtain EA Approval." This function is followed by an "LE" or exit and represents a failure of the company to obtain EA approval. If the company fails to obtain EA approval, then they will exit the entire aquaculture permitting process and will not receive approvals to operate.

d. Function 1.4, "Conduct Environmental Impact Statement"

If the company management instead chooses to pursue function 1.4 rather than 1.3, "Conduct Environmental Impact Statement," then it must complete all the same steps that the EA requires along with conducting a cultural impact statement. The company of one of the interview subjects chose to pursue the EIS due in part to the scope of their proposed operations which they felt might bring greater scrutiny to bear on potential cultural impacts.

The fourth function of the high-level permitting process is function 1.4, "Conduct Environmental Impact Statement." This function is in parallel with function 1.3 "Conduct Environmental Assessment" and represents an alternative path due to being nested in an "OR" node (Figure 8). The Environmental Impact Statement (EIS) is essentially a more rigorous version of the EA. This is due to the need to conduct a study and justification of the impact on culturally significant sites in the vicinity of the proposed area of aquaculture operations. The company of one interview subject had recently performed an EIS and provided extensive information about the EIS process.

The decomposed FFBD for function 1.4 is shown in Figure 8. It begins with an "AND" node that contains two branches. The first branch goes to function 1.4.1 "Perform all Functions of 1.3." This was chosen as a shorthand way of showing that the organization that completes an EIS will necessarily perform all of the same functions of an EA.

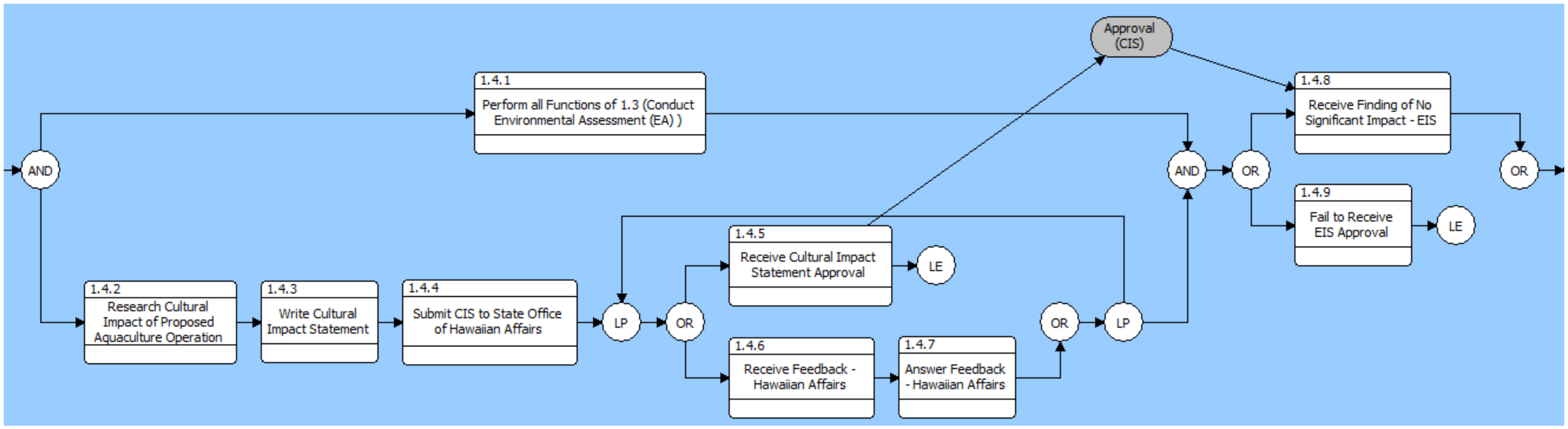


Figure 8. Function 1.4 Decomposition

The second branch of the initial "AND" node shows much of the difference between an EA and an EIS. This branch begins with function 1.4.2, "Research Cultural Impact of Proposed Aquaculture Operation" (Figure 8). In completing this function, the company must determine what cultural, historic, or native sites are in the area. Cultural sites are of particular importance to Hawaii and Hawaiians due to the large native population and the uniqueness of Hawaiian culture. These sites include, for example, burial grounds, sacred fishing grounds, religious sites, and significant Hawaiian historical locations. In completing this step, the company performs research and gather data. Many cultural sites exist which are not well documented, but the burden remains on the company to determine where conflicts may exist.

After performing this research, the company will perform function 1.4.3, "Write Cultural Impact Statement" (Figure 8). This statement, or report, serves as an addition to the final EA report. It documents the company's understanding of the cultural significance of an intended area of operations, and the company's plan to minimize or eliminate disturbances to the area. The company then performs function 1.4.4, "Submit Cultural Impact Statement to State Office of Hawaiian Affairs" (Figure 8). Due to the sensitivity of cultural issues and the prevalence of native sites, the state has set up the Office of Hawaiian Affairs to deal with such issues. The office is charged with reviewing the report and either approving or providing feedback on the company's plan for minimizing or mitigating any impact on native cultural sites.

At this point in the process, the company enters the now familiar loop construct for agency feedback. If the Cultural Impact Statement is immediately approved, then the company executes function 1.4.5, "Receive Cultural Impact Statement Approval" (Figure 8). If, however, the statement is not approved, then the Office of Hawaiian Affairs provides feedback to the company on portions of the plan that require adjusting. This is seen in function 1.4.6, "Receive Feedback – Hawaiian Affairs." The company answers the feedback in function 1.4.7, "Answer Feedback – Hawaiian Affairs." Then the process loops to the beginning of the loop construct. When the company finally executes function 1.4.5, it may exit the loop and move on to the subsequent "OR" node, provided it has also completed function 1.4.1. The FFBD shows that function 1.4.5 provides an input, in the form of an approved Cultural Impact Statement, to function 1.4.8 (Figure 8).

After the company completes functions 1.4.1 – 1.4.7, they enter another "OR" node (Figure 8). The first branch is to function 1.4.8 "Receive Finding of No Significant Impact" and serves as an approval of the entire EIS. If at some point the company fails to receive all of the approvals of the EA or the Cultural Impact Statement, then it exits the process via the "LE" node at the end of function 1.4.9, "Fail to Receive EIS Approval." This serves as an exit from the entire high-level FFBD and indicates that the company has not received the necessary permits to conduct its proposed aquaculture operation.

2. Function 1.5, "Obtain National Pollutant Discharge Elimination System NPDES"

Function 1.5 is to "Obtain National Pollutant Discharge Elimination System (NPDES)" permit (Figure 9). This permit is a requirement of the U.S. Environmental Protection Agency (EPA) but is managed by the State of Hawaii Department of Health. The EPA has empowered the Department of Health to oversee the NPDES permitting process. The NPDES is a system by which the U.S. government manages the pollutants that are discharged into the ocean. Interview subjects stated that NPDES mainly addresses pollutants released from land operations, such as sewage or factory discharges, aquaculture operations are also required to get NPDES permits. The thought process behind this requirement is that a relatively large concentration of fish in one confined area has the potential to create a pollution hazard, due in particular to the waste that the fish produce. In this step, the aquaculture company must prove that its operation will not excessively pollute the surrounding environment.

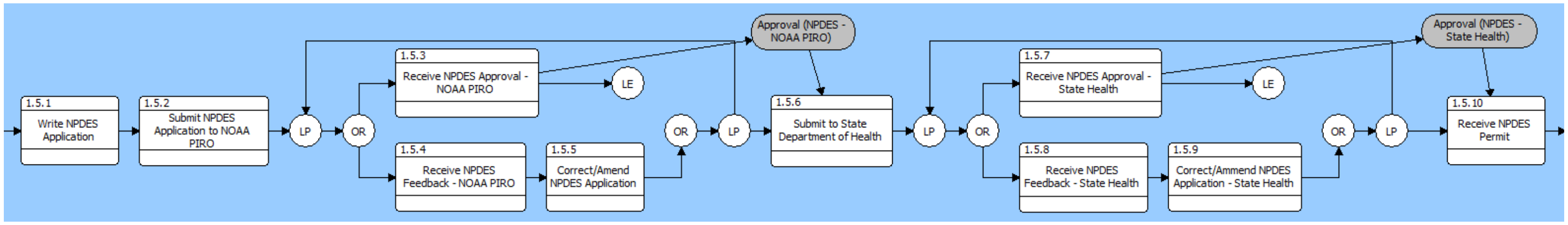


Figure 9. Function 1.5 Decomposition

The decomposed permit application process consists of ten separate functions and two loop constructs (Figure 9). The first function is 1.5.1, “Write NPDES Application.” In this step, the company completes the required paperwork in preparation for submission. Next, function 1.5.2, “Submit NPDES Application to NOAA PIRO,” requires the company to submit the completed application to the NOAA Pacific Islands Regional Office (PIRO).

Once submitted, the first loop construct is encountered. If approved outright, the company will complete function 1.5.3, “Receive NPDES Approval – NOAA PIRO” (Figure 9), If, however, the application is not approved then the company completes function 1.5.4, “Receive NPDES Feedback – NOAA PIRO.” If feedback is received, the company alters their application in response to the feedback in function 1.5.5 “Correct/Amend NPDES Application.” Then the process loops back to the beginning. Once approval is finally received the loop is exited via the “LP” node to function 1.5.6.

Function 1.5.6, “Submit to State Department of Health,” receives an input from function 1.5.3 in the form of a NOAA PIRO approved application (Figure 9). The Department of Health has been empowered by the EPA to perform final review and approval of the NPDES permitting process. After submitting to the Department of Health, an identical loop construct is entered and the functions within the loop are carried out in the same manner. When Department of Health approval is finally gained, the loop is exited to function 1.5.10, “Receive NPDES Permit,” which receives a State Health approval input from function 1.5.7.

3. Function 1.6, “Obtain Conservation District Use Permit (CDUP)”

Function 1.6 is “Obtain Conservation District Use Permit” (Figure 10). A Conservation District Use Permit (CDUP) is a permit administered by the State of Hawaii Department of Land and Natural Resources (DLNR). This permit must be acquired by the marine aquaculture company to secure the rights to a specific area of ocean for conducting aquaculture operations. It is often the final permit obtained but may be pursued in parallel with the Section 10 and NPDES permits. The Conservation District Use Permit (CDUP) seems to represent the least complex part of the process of obtaining necessary permissions for aquaculture operations. A CDUP is the method by which the State Department of Land and Natural Resources gives a company permission to use an ocean space for something such as aquaculture. The decomposition of function 1.6 begins with function 1.6.1, "Write CDUP Application" (Figure 10). This function starts the process by gathering and completing necessary paperwork for the CDUP. Once the application is written it is submitted to the DLNR by function 1.5.2, "Submit Application to DLNR Board."

The application process was described by the interview subjects as being fairly straightforward and so the decomposed FFBD next contains a simple "OR" node with two branches (Figure 10). One branch is to function 1.5.3, "Receive Permit Approval," and the other branch is to function 1.5.4, "Receive Permit Disapproval." If a company executes function 1.5.3, then it will move on with the overall high-level process. If a company executes function 1.5.4, then it will exit the process via the "LE," and will have failed to secure all necessary permits and will not be able to conduct its proposed operations.

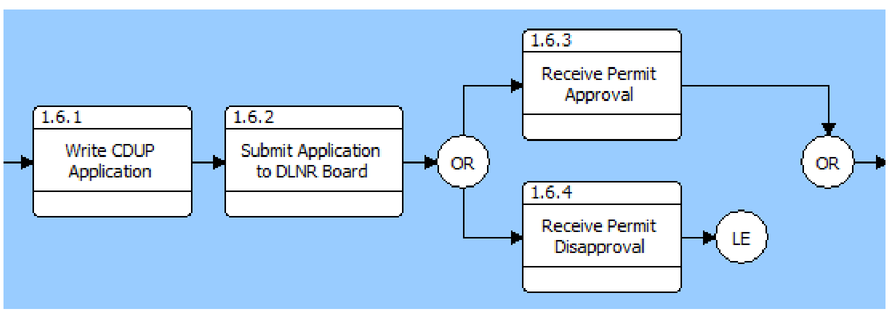


Figure 10. Function 1.6 Decomposition

4. Function 1.7 "Obtain Army Corps of Engineers Section 10 Permit"

The final branch of the "AND" node is function 1.7, "Obtain Army Corps of Engineers Section 10 Permit." The Section 10 permit is a requirement of the U.S. Army Corps of Engineers that allows an organization to permanently anchor objects to the seafloor. Nearly all aquaculture companies make use of large cages or pens that are suspended in the water column. The pens normally feature a buoy or system of buoys to keep it suspended and a tether to an anchor to prevent it from drifting with the tides and currents. It is this tethered anchor configuration that leads to the need for a Section 10 permit. Procurement of a Section 10 permit is a layered process, though, which requires pursuing several additional permits. A standard net pen design used to enclose fish in offshore aquaculture is shown in Figure 11.

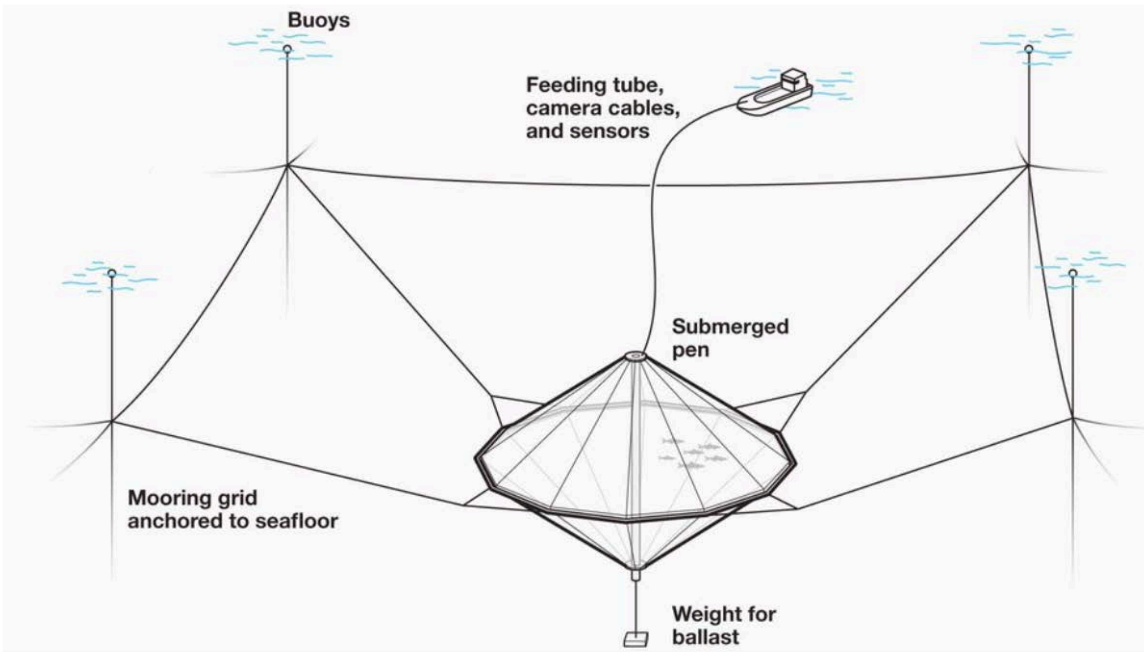


Figure 11. Example of Net Pen with Anchored Moorings. Source: National Geographic (n.d.).

Function 1.7 is a relatively involved part of the entire high-level FFBD. One interview subject described this process as containing four separate permits: a NOAA endangered species permit, a NOAA benthic habitat permit, an Office of Hawaiian Affairs Permit, and a Coastal Zone Management Permit. These permits and the subsequent Army Corps of Engineers Approval allow the company to anchor gear to the ocean floor. The decomposition contains several loop constructs and parallel paths (Figures 12 and 13).

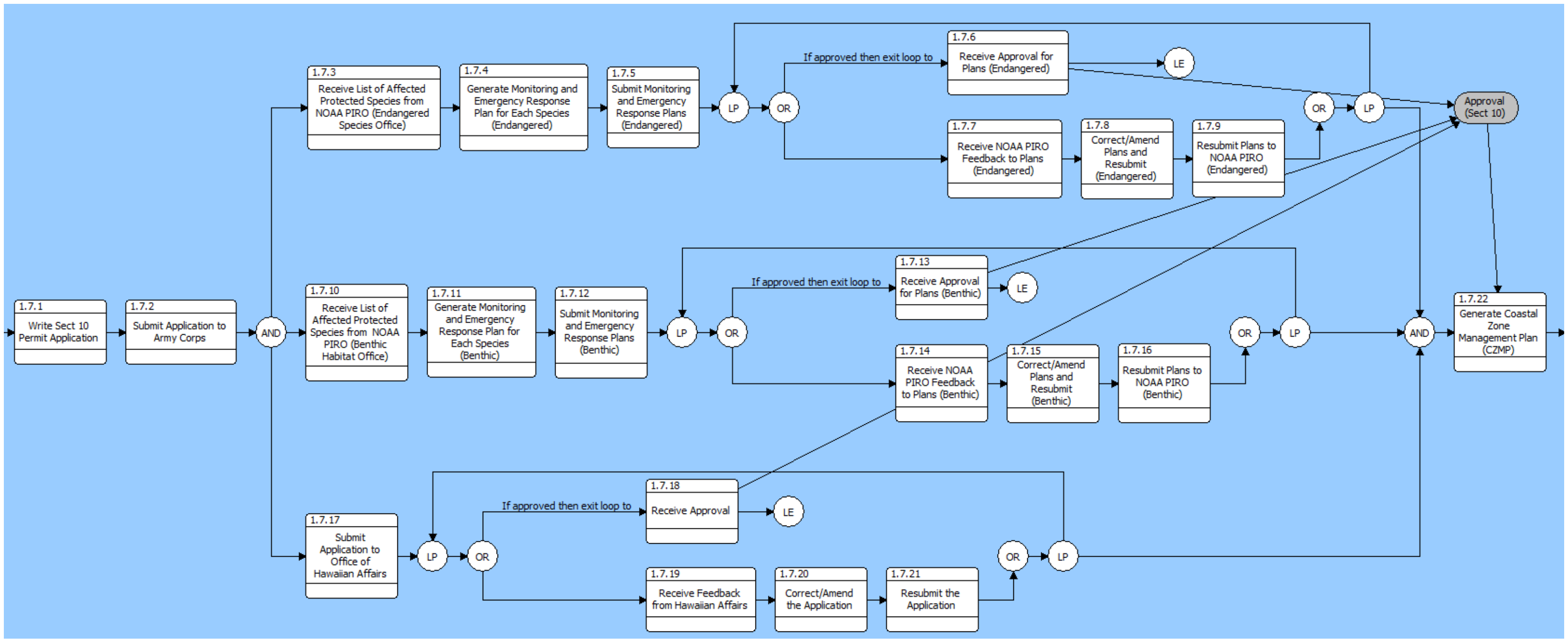


Figure 12. Function 1.7 Decomposition, Part 1

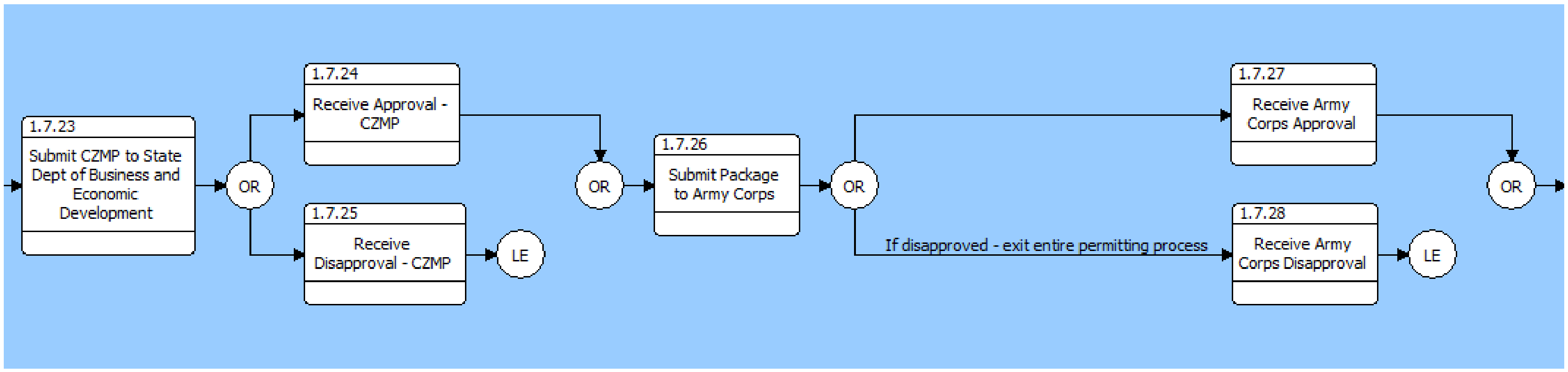


Figure 13. Function 1.7 Decomposition, Part 2

The process begins with function 1.7.1, “Write Sect 10 Permit Application” (Figure 12). Once the application is complete, the company submits it by means of function 1.7.2, “Submit Application to Army Corps.” The Army Corp of Engineers then distributes the permit application to three agencies which provide feedback to the company. For this reason, the decomposed FFBD enters an “AND” node with three branches. The first branch goes to function 1.7.3, “Receive List of Affected Protected Species from NOAA PIRO (Endangered Species Office).” In this function, the company gets a list of endangered or protected species that NOAA PIRO feels need specific plans for protection. The company must then generate monitoring and emergency response plans for each species in function 1.7.4 (Figure 12).

For example, NOAA PIRO (Endangered Species Office) might tell the company that based on the proposed net pens and area of intended operation, the company must develop plans to monitor and report on the presence of any Hawaiian monk seals. The plan will also need to include an emergency response to outline the company’s plan of action should any Hawaiian monk seal become endangered by the company’s equipment. These plans are required to be detailed and specific. Marine aquaculture companies operating in Hawaii are generally required to draw up such plans for numerous species.

Once the monitoring and emergency response plan is written, it is submitted by way of function 1.7.5 (Figure 12). At this point a loop construct is encountered. If the plan(s) is approved, then the company will exit the loop from function 1.7.6, “Receive Approval for Plans (Endangered).” If the plan(s) is not approved, then NOAA PIRO will provide feedback at function 1.7.7, “Receive NOAA PIRO Feedback to Plans (Endangered).” The company then must execute function 1.7.8, “Correct/Amend Plans and Resubmit (Endangered)” in order to fix any deficiencies that were pointed out. Next, the company must resubmit the plan(s) in function 1.7.9. The process then loops to the beginning and the loop continues until all of the plans for all of the required species receive approval.

The second branch of the “AND” node is identical to the first branch in structure and function, except that the second branch deals with NOAA PIRO – Benthic Habitat

Office (Figure 12). This office provides a set of benthic, or bottom dwelling, species to the company for which it must again provide monitoring and emergency response plans.

The final branch of the "AND" node deals with the Office of Hawaiian Affairs (Figure 12). This branch is similar to the Cultural Impact Statement from the Environmental Impact Statement. The company must demonstrate to the Office of Hawaiian Affairs that they are not anchoring gear on top of sacred cultural sites or affecting native sites in other ways. The application is submitted to the Office of Hawaiian Affairs in function 1.7.17. Then another loop process is entered with additional feedback, correct, and resubmit functions.

Once approval from the NOAA PIRO Endangered Species, NOAA PIRO Benthic Habitat, and the Office of Hawaiian Affairs is received, the approvals provide an input to function 1.7.22, "Generate Coastal Zone Management Plan (CZMP)" (Figure 12). This plan, required by the U.S. government, must be submitted to the State of Hawaii Department of Business and Economic Development, which is empowered to review and approve the plan as part of function 1.7.23 (Figure 13). If the plan is approved, the company completes function 1.7.24. If, however, the plan is disapproved, then the company completes function 1.7.25 and exits the process.

If the company receives an approved CZMP, then it submits a final package to the Army Corps of Engineers that documents that all prior functions were completed. The Army Corps of Engineers then reviews the entire package. If the Corps approves, then the company executes function 1.7.27 and exits the decomposed FFBD (Figure 13). If the Corps disapproves, then the company executes function 1.7.28 and exits the entire high-level process. One interview subject singled out the Army Corps of Engineers review and approval process as being among the longest review periods throughout the entire aquaculture permitting process. The company of this individual felt that in one case, it was necessary to reach out to the office of a U.S. senator to prod the local Army Corps of Engineers office into action and move the process along. Since contacting a U.S. senator is not an official part of the permitting process, this step was not included in the decomposed FFBD.

5. Function 1.8, "Secure a Lease"

The final part of the decomposed FFBD is function 1.8, "Secure Lease" (Figure 14). Once all previous functions are completed and permission to conduct aquaculture operations has been obtained, the company must secure a lease. Similar to a lease on a building or a piece of land, this lease provides the company with the legal right to begin conducting their operations within the bounds of all the permits received in the previously completed functions. Securing a lease can be a somewhat prolonged process due to the uncertainty of ocean space valuation.

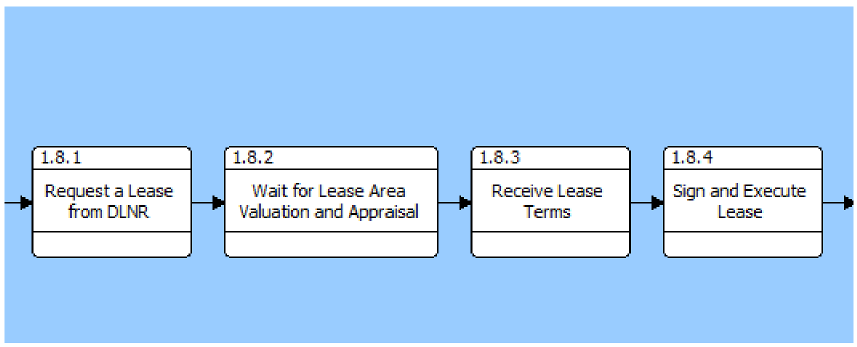


Figure 14. Function 1.8 Decomposition

Function 1.8.1 requires the company to request a lease from the DLNR (Figure 14). Then, in function 1.8.2, the company must wait for a lease area valuation and appraisal. This was described as problematic because appraisal of ocean space is difficult when comparable uses of the ocean are uncommon. Land appraisal by contrast is relatively simple and well understood. One can compare to similar plots of land with similar uses and come to a reasonable valuation for a lease. The ocean lease, however, normally suffers from a lack of comparable leases. This can draw out the process and lead to unexpected cost for the lease.

Function 1.8.3, "Receive Lease Terms" (Figure 14) occurs when the company finally gets the terms of the lease, including the lease period, lease area, and lease cost. If the lease terms are acceptable, the company signs the lease in function 1.8.4. Once signed, the company is free to execute the final function 1.9, “Begin aquaculture operations.”

This completes MEAD step 3, which is to define unit operations and work process. The next series of steps in the MEAD methodology are steps 4-6, which all involve identifying variances.

D. VARIANCE MATRIX

The next step toward understanding the marine aquaculture permitting process and in turn, recommending requirements for CMSP decision support tools, is to understand the variances inherent in the process and the effects on the companies seeking permits. Recall that variances are not necessarily classified as problems but as alterations or unexpected process outputs (see Chapter II, Section B).

In analyzing and understanding the variances captured during the interviews that are intrinsic to the aquaculture permitting process, it was necessary to both look at the specific interview questions that pertained to variances as well as scan the entirety of the interview transcripts. Some interview responses provided clear examples of process variances, while identifying other variances required some interpretation and analysis of the responses.

The first step to understanding and mapping the variances involved listing all variances found in the interview transcripts. This resulted in a total of 18 distinct variances (Table 3). These variances were then matched to their corresponding unit operations (third column of Table 3). Matching variances to unit operations helped provide clarity and traceability in the process of identifying the variances. The right column of Table 3 matches the affected unit operation to the corresponding function number of the high-level FFBD to provide further. Traceability was important in developing the requirements recommendations for the CMSP decision support tools and for improving marine aquaculture permitting.

Table 3. List of Variances

No.	Variance	Affected Unit Operation	Function Number
1	Assessed Cost of Permitting Operations	Business Plan	1.1
2	Number of Participants	Scoping Meetings	1.2
3	Access to Historical Data	EA	1.3
4	Weather	EA	1.3
5	Cost of 3rd Party Modeling	EA	1.3
6	Need for Oceanic Current Data	EA	1.3
7	Results of Oceanic Current Analysis	EA	1.3
8	Volume of Public Comments	EA	1.3
9	Agency Response/Review Time—EA	EA	1.3
10	Travel to HNL for Coordination	EA	1.3
11	Prevalence and Significance of Cultural Sites—EIS	EIS	1.4
12	Agency Response/Review Time—NDPES	NDPES	1.5
13	Number of Monitoring Plans Required	Sect 10	1.6
14	Prevalence and Significance of Cultural Sites—Sect 10	Sect 10	1.6
15	Volume of Feedback	Sect 10	1.6
16	Agency Response/Review Time—Sect 10	Sect 10	1.6
17	DLNR Board Responsiveness/Review Time	CDUP	1.7
18	Assessment Value	Lease	1.8

The second step in analyzing the variances involved placing the variances in a matrix format. As described in Chapter II, Section B, there are several ways to make a variance matrix. This thesis uses a format similar to the example provided in Taylor and Felten (1993) because that format highlights the relationships between the variances. In this format, the unit operations are listed vertically down the left side. The variances appear in the right portion of the matrix and are grouped so that each variance is matched with its corresponding unit operation. The variance numbers are listed twice. First they are listed vertically on the left side of the variance portion of the matrix. Second, they are listed diagonally on the right side of the variance portion of the matrix. This method of listing the variance numbers twice facilitates relationship identification.

The third step in understanding variances within the matrix format was to go through the matrix, one variance at a time, and place an "x" where there was a relationship between variances. Relationships were identified by either direct statements from interview subjects or inference from the data provided in the transcripts. A relationship does not imply causality, although it is possible that a causal relationship exists between some variances (Taylor and Felten, 1993). For instance, travel to Honolulu for coordination (variance 10) is related to agency response/review time in the EA (variance 9) since a slow response by the agencies involved in the EA review may require a greater amount of proactive effort, and therefore more travel, on the part of the company trying to complete an EA. The agency response, however, does not cause a specific amount of travel or a defined number of trips by company management. This third step of variance analysis identified 47 distinct relationships between the defined variances.

Identification of the key variances was the final step in our variance analyses. Variances within a variance matrix can be considered key if they have the potential to produce a large effect on the process. Taylor and Felten (1993) describe two ways in which key variances can impact the process: "through their *direct* impact on the final product or through their *indirect* effects on many other variances, through a chain of events otherwise impossible without the originating variance."

The analysis of the 18 variances in Table 4 led to the identification of six of those variances as key variances—variances 1, 3, 8, 9, 12, and 16. These six are shown in bold font in Figure 15 with a circle around their variance number. This figure shows the 18 variances from Table 4 arranged so that the relationships between variances can be readily determined. The x entries indicate a relationship exists between the intersecting variances.

Unit Operations	#	Variances	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Business Plan	1	**1: Assessed Cost of Permitting Operations**																	
Scoping Meeting	2	2: Number of Participants																	
EA	3	**3: Access to historical data**	X																
	4	4: Weather																	
	5	5: Cost of 3rd Party Modeling	X		X														
	6	6: Need for Oceanic Current Analysis	X		X		X												
	7	7: Results of Oceanic Current Analysis						X											
	8	**8: Quantity or Type of Public Comments**	X		X			X	X										
	9	**9: Agency Response/Review Time - EA**	X		X					X									
	10	10: Travel to HNL for coordination	X								X								
EIS	11	11: Prevalence and Significance of Cultural Sites - EIS			X				X	X	X								
NDPES	12	**12: Agency Response/Review Time - NDPES**	X		X				X	X									
Sect 10	13	13: Number of Monitoring Plans Required	X							X									
	14	14: Prevalence and Significance of Cultural Sites - Sect 10			X				X	X			X						
	15	15: Quantity or Type of Feedback	X		X				X	X					X	X			
	16	**16: Agency Response/Review Time - Sect 10**	X		X					X					X	X	X		
CDUP	17	17: DLNR Board Responsiveness/Review Time	X																
Lease	18	18: Assessment Value	X										X			X			

Figure 15. Key Variances Matrix

Variance 1, assessed cost of permitting operations, was identified as a key variance due to the large number of relationships between it and the other variances—a total of twelve relationships. All of the other variances can add to the cost of permitting operations. Therefore, failure to properly assess the cost can result in significant consequences to the company. Under assessment may mean a failure to raise or allocate sufficient capital toward the project. Over assessment means that the company may tie up capital that could have contributed to other company functions and operations

The second key variance is variance 3, access to historical data, which is related to nine other variances. Variance 3 is a key variance due to its large number of relationships and because historical data relating to oceanic currents, local seawater chemistry, benthic composition, and more is extremely useful for completing the environmental assessment. It makes third party modeling (variance 5) simpler with fewer assumptions required. It reduces or potentially eliminates the need for an oceanic current analysis (variance 6). It can affect the quantity or type of public comments (variance 8) by providing deeper justification for the company's assertions in the draft EA. Historical data can also improve agency responsiveness and review time because it may head off potential questions that would arise from an absence of such data. In other words, a company's ability to obtain historical data presents enormous implications to the EA process in particular. It also affects subsequent unit operations due to the basis of justification that historical data can provide when applying for permits, writing monitoring and emergency response plans, and accounting for culturally sensitive sites.

Variance 8, quantity or type of public comments, is considered key because of the potential to add additional requirements to the permitting process and to eventual aquaculture operations. One interview subject's testimony in particular drove the discovery of this variance and its consideration as key. The subject stated that a part of one of their monitoring plans is to conduct water testing for mercury in their area of operations. He stated that the agency requiring this test acknowledged it as unnecessary but was driven to add the requirement due to public comments in the EA process and a fear of lawsuits. He went on to say that public comments and pressure, particularly from powerful NGOs, can drive parts of the permitting process.

Variances 9, 12, and 16, agency response/review time—EA, NPDES, and Sect 10, respectively—are considered key due to the widely ranging times required to get through the review portion of the EA process. There is no set timeline for the process and some interview subjects expressed great frustration with the extreme length of time required for agency reviews in all phases of the permitting process. From the interview subjects' perspectives, extended review times can negatively impact a company's ability to commence operations, return a profit, pay down debt, and get product to market.

Two factors identified by the interview subjects as contributing to long review times are a lack of coordination between the reviewing agencies and redundancies in the permitting process. All three interview subjects expressed frustration with the lack of coordination. They recounted how their companies had to answer questions or requests for information from one agency, and then were asked for the same things by another agency. From the interview subjects' perspectives, lack of coordination and redundancy problems can lead to significant extra expenditures of company resources and setbacks in permitting timelines.

E. VARIANCE CONTROL TABLE

The analysis results discussed in the preceding sections were based on using MEAD steps 4 and 5 to identify variances and create the key variance matrix. The results from the use of MEAD step 6 to creating a key variance control table and a role network are presented in this section. For clarity, the variance control table results are presented in this section and the role network results are presented in the following section.

The key variances can be mapped to both their unit operations and to proposals to mitigate the negative effects of the key variances and improve the permitting process. The mitigation proposals were developed by objective analysis of the interview transcripts. Table 4 shows the mapping of the key variances to the unit operations and functions, and to the proposed mitigations.

Table 4. Key Variance Mapping

Key Variance	Unit Operations/Functions	Proposed Capabilities to Address Variance
Assessed Cost of Permitting Operations	1.1 Create Business Plan	Layers that provide robust data useful in aquaculture permitting.
Access to Historical Data	1.3 Conduct Environmental Assessment (EA)	Layers that provide robust data useful in aquaculture permitting.
Quantity or Type of Public Comments	1.3 Conduct Environmental Assessment (EA)	Integrate a cloud based public comment forum.
Agency Response/Review Time - EA	1.3 Conduct Environmental Assessment (EA)	Integrate a cloud based central hub feature for the aquaculture permitting process.
Agency Response/Review Time - NDPES	1.5 Obtain National Pollutant Discharge Elimination System (NPDES)	Integrate a cloud based central hub feature for the aquaculture permitting process.
Agency Response/Review Time - Sect 10	1.7 Obtain Army Corps of Engineers Section 10 Permits	Integrate a cloud based central hub feature for the aquaculture permitting process.

Table 4 shows that there are three general capabilities proposed to mitigate the key variances. The first is that the decision support system should be capable of providing a publicly accessible web-based data portal with mapping and overlay capabilities. Such a portal could provide layers on a map or chart that provide robust data for aquaculture permitting. This capability helps address both the underlying cost incurred by a company and the difficulties associated with gaining historical data. Second, in order to address the quantity or type of public comments received during the EA process, the decision support system should be capable of integrating a cloud based, or publicly accessible web-based, public comment forum. While this will not necessarily impact the number of comments, it will make addressing them easier and therefore minimize the impact of this key variance overall. Finally, the decision support system should provide the capability of integrating a cloud based, or publicly accessible web-based, central hub that can be used by all stakeholders involved in the permitting process. This capability goes a step beyond providing a simple decision support system and provides a more complete tool for use by all parties involved in aquaculture permitting.

These capabilities provide a basis for the formulation of the capability requirements that are the ultimate goal of this thesis. In order to finish MEAD step 6, the author developed a role network that provided further insights that may be useful in building capability requirements for CMSP decision support tools.

Table 5. Requirements Table

Requirement Number	Requirement Type	Requirement Header
1.0	Capability	CMSP Decision-support system Interactive Chart (DSS IC)
1.0.1	Capability	CMSP DSS IC - Integrated NOAA Standard Nautical Chart
1.0.1.1	Maintainability	CMSP DSS IC - Integrated NOAA Standard Nautical Chart Monthly Update
1.0.2	Capability	CMSP DSS IC - Integrated Ocean Current Vectors
1.0.3	Capability	CMSP DSS IC - Integrated Culturally Significant Areas
1.0.3.1	Capability	CMSP DSS IC - Integrated Culturally Significant Areas - Description
1.0.4	Capability	CMSP DSS IC - Integrated Layer of Threatened and Endangered Species
1.0.4.1	Capability	CMSP DSS IC - Integrated Layer of Threatened and Endangered Species - Cross Reference
1.0.5	Capability	CMSP DSS IC - Leased Areas
1.0.5.1	Capability	CMSP DSS IC - Leased Areas - Cross Reference
1.0.5.2	Usability/ Maintainability	CMSP DSS IC - Leased Areas - Updates
1.0.5.3	Usability/ Maintainability	CMSP DSS IC - Leased Areas - Updates
1.1	Capability	CMSP Decision-support system Central Hub (DSS CH)
1.1.1	Capability	CMSP DSS CH - Transparency
1.1.2	Capability	CMSP DSS CH – Publically Accessible (Cloud Based)
1.1.3	Capability/ Usability	CMSP DSS CH – Publically Accessible (Cloud Based)

F. ROLE NETWORK

A role network that was developed as a part of this analysis and in accordance with MEAD step 6. Thus the role network represents primarily the perspectives of the companies. The role network was identified in an effort to understand how, from the companies' perspectives, the interactions described by the role network might be made more efficient or otherwise improved. The role network was also developed to determine who in the role network might use specific CMSP decision support tools, and how those tools might be used. In these ways, the role network provided insights that proved useful in requirements generation.

Figure 16 shows a diagram of the role network. The focal point of the diagram is the company management. The company management, normally the top person at the company, is the central point of all permitting operations. The reasons for this are twofold, based on responses from the interview subjects. First, the Hawaiian marine aquaculture companies are relatively small in terms of work force. Almost all had fewer than 20 full time employees. Second, permitting normally proves so difficult that company management feels the need to maintain near complete control of the process rather than entrust it to a lower level employee. This speaks to the sensitive nature of permitting, the potential politics involved, and the risks involved in proposing and attempting to start up a new marine aquaculture operation.

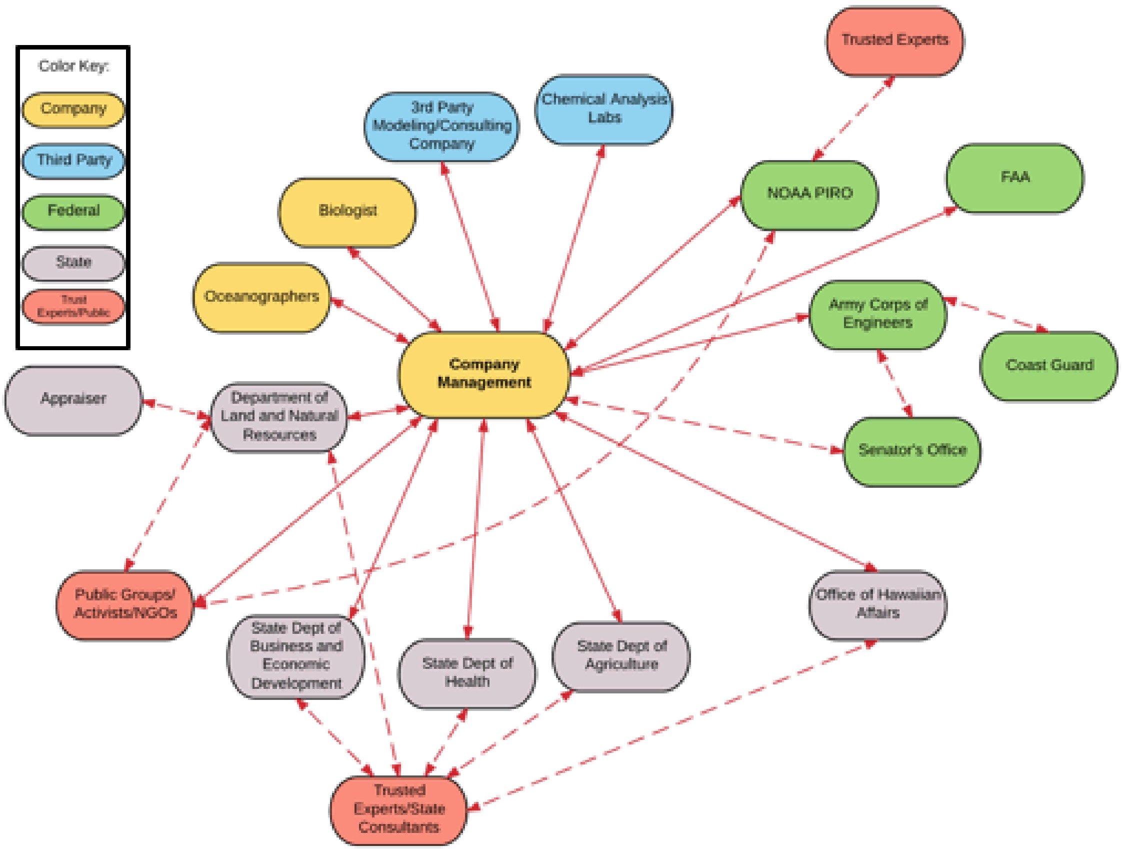


Figure 16. Role Network

All of the arrows in the role network diagram (Figure 16) are two-way arrows. No one-way interactions or lines of communication were identified in the course of the analysis. Every level of aquaculture permitting, even with government agencies, involves a back and forth dialogue between two connected roles.

The yellow elements in the role network represent company employees. Company management interfaces with two specific employees during the course of permitting; biologists and oceanographers. These employees are charged with tasks such as data collection for the EA or EIS, sample gathering, and some limited document processing and spreadsheet making. These employee elements are placed very close on the role network diagram due to the intimate relationships between employees of the company and the company management.

Blue elements in Figure 16 represent third party companies who aid in the EA or EIS process. These are placed somewhat farther away than the actual company employees but still relatively closely to the focal company management element. The third party agencies are only involved in permitting for one part of the process, the EA or EIS, but they provide a significant amount of modeling and data analysis. Additionally, there is an exchange of payment for services between company management and the third party companies.

The green elements in Figure 16 represent federal government agencies and entities. Three of them have direct, solid-lined, links with the company management focal role. These are NOAA PIRO, FAA, and the Army Corps of Engineers. All three of these directly communicate with the focal role during the course of the permitting process. The FAA element is placed relatively far from the company management because the FAA is only consulted for operations close to an airport. The Senator's office element is at the end of a dashed line to show that the communication between the focal role and the office is informal and not required by the permitting process. One interview subject described how their company contacted the Senator's office in order to put pressure on the local office of the Army Corps of Engineers. In that situation, the interview subject asserted that the Army Corps persistently delayed reviewing Section 10 permit applications. Thus, the company management felt it necessary to involve the office of the Senator to move the review along. For this reason, there is also a dashed line between the Senator's office and the Army Corps of Engineers. Lastly, the Army Corps also consults with the Coast Guard for Section 10 permitting due to the potential for navigational obstructions when tethering aquaculture equipment to the ocean bottom. Again, this is a dashed line because the Coast Guard is consulted rather than directly involved in the process.

Grey bubbles show State of Hawaii agencies and roles. Five of the six are linked to the focal role directly with solid, two-way arrows. These include Department of Land and Natural Resources (DLNR), State Department of Business and Economic Development, State Department of Health, State Department of Agriculture, and the Office of Hawaiian Affairs. DLNR was placed close to the focal role since one interview subject described them as a "coordinating agency." The interview subjects indicated that this coordination seems to be informal and mostly by default rather than by edict. The lone state entity not directly connected to the focal role is the appraiser. The appraiser's office decides on the ocean space value and sets the cost of the lease, and then delivers the assessment information to DLNR.

Finally, there are three red elements in Figure 16 representing public groups and trusted experts that are not directly involved in decision-making but that influence decision makers in the permitting process. Public groups, activists, and NGOs can exert influence on state and federal agencies. However, their influences are most strongly felt by NOAA PIRO and DLNR, according to the interview subjects. For this reason, and to prevent over-complicating the diagram, the element for public groups is only connected to NOAA PIRO and DLNR by way of a dashed line. It is also connected directly to the focal role, mainly due to the public comments period in the EA and EIS processes. Finally, all state agencies and NOAA PIRO consult with trusted experts such as universities laboratories, foundations, and research groups as a part of the approval process.

The role network provides three key insights. First, there are many interactions that occur in the permitting process. The company management in the focal role must interface formally with thirteen distinct entities and informally with another one. The number of interactions further confirms that the process for obtaining an aquaculture permit is complex.

Second, there are, apparently, only limited interactions between the key agencies involved in the process, based on the information we obtained from the interview subjects. For example, the interview subjects indicated that Army Corps of Engineers does not discuss the permit request with the NOAA PIRO or to the Office of Hawaiian Affairs, even though all three are involved in Section 10 permitting. The limited agency interactions seem to occur when permit applications are forwarded from one department to another. Based on the interviews, however, this communication is non-existent in the course of reviewing permit applications. Each interview subject described how agencies contacted the company managers with: (a) requests for information already requested by another agency; and (b) questions on the progress of another agency's review of the permit application. This often resulted in the company managers responding to the same requests several times over, in writing, to several different agencies.

Finally, the interview subjects described a lack of a hub for coordination among the agencies. DLNR was said to be an informal coordinating agency, but the amount of coordination is apparently small and thus is not represented by any arrows in the role network diagram (Figure 16).

All three of these insights indicate that there is potential for improving the marine aquaculture permitting process. CMSP decision support tools could potentially help provide these improvements—for example, by providing publicly accessible: (a) data portals that improve access to the data sets, and to data visualization and analysis tools, that are needed by companies, agencies, NGOs, trusted experts, and the public; (b) web sites for sharing information and comments; and (c) web sites for conducting coordinated reviews of permit applications. The ways in which CMSP decision support tools can help are more fully explored in Chapter V.

Finally, the completion of MEAD step 6 allows for providing recommended capability requirements for CMSP decision support tools. These requirements, if adopted, would represent guidelines for the development of decision support tools. The MEAD approach to developing these requirements means that the requirements would be traceable to capabilities that address the key variances identified from the marine aquaculture interviews. These requirements are discussed in Chapter V.

V. RECOMMENDED REQUIREMENTS

All previous analysis was conducted in order to inform the creation of recommended requirements for the decision-support system that is being proposed for the CMSP Pacific Islands Regional Planning Body (PIRPB). The reader will recall that such a decision-support system is one of the main deliverables of the Naval Postgraduate School (NPS) project that is a part of the CMSP effort (Murphree and Guest 2015). These requirements form a portion of the first step in system design of the decision-support system. The development of such requirements is a standard part of the design of systems, including sociotechnical systems, such as decision support systems (Blanchard and Fabrycky 2006). Because of the limitations of this study, the following requirements are not all inclusive. Rather, these requirements are specific to the nature of the work done in this report and are intended to serve as initial guidelines for developing a final set of requirements for a CMSP decision support system. These requirements do not necessarily fully address such critical system design aspects such as maintainability, usability, capability, and more.

The requirements formed during the course of this analysis may help provide a firm foundation for the future potential of the decision-support system and are all traceable to the desired functions of CMSP listed in the PIRPB presentation on CMSP (Griffin 2015). The PIRPB identified three general functions of CMSP. These include:

1. Identify areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, and preserve critical ecosystem services to meet economic environmental, security, and social objective.

2. Provide an integrated, comprehensive, ecosystem-based, flexible, and proactive approach to planning and managing uses and activities.

3. Reduce or eliminate user conflicts, increased cost and delays from planning and regulatory inefficiencies, and the potential loss of critical economic, ecosystem, social, and cultural services for present and future generations. (Griffin 2015)

Additionally, many of the recommended requirements support the roles and benefits for the Department of Defense (DOD) described by Griffin (2015):

1. Further the National Ocean Policy as directed, by assisting in the development of the Regional Plan.
2. Officers can develop stakeholder engagement skills outside of the Navy, in the community.
3. Officers develop research skills with other agencies, educational institutions and stakeholder organizations.
4. The Plan provides the Navy and DOD with information of other ocean uses—Services can use this data in siting training, natural resource permitting, selecting new training areas and encroachment.
5. The Plan provides visibility (unclassified) of DOD training and testing areas to other ocean users so that they can site their activities with reduced conflict. (Griffin, 2015)

Subsequent discussion will refer to CMSP functions or DOD benefits by the number shown on the preceding list.

A. OVERALL REQUIREMENTS TABLE

There are 16 recommended requirements. These requirements are summarized in Table 5 and described in detail in the following paragraphs. The requirements cover three types of requirements: capability, maintainability, and usability. Capability addresses what the system can do and how well it can do it. Maintainability addresses how easily the system can be serviced and updated. Usability, meanwhile, describes the ease with which a user can operate the system.

B. DETAILED REQUIREMENTS DISCUSSION

The following paragraphs describe the recommended requirements, including their basis and rationale, how they address the key variances, and their potential benefits to the DOD. For conciseness, the requirements are written following the guidelines of MIL-STD-961E, Military Standard: Defense and Program-Unique Specifications Format and Content (MIL-STD-961E, 2015), which is the DOD reference document for writing system specifications and requirements.

1. Decision-Support System Interactive Chart

The first set of detailed requirements, those with a number beginning with 1.0 (Table 6), pertain to the CMSP decision-support system interactive map or chart. They provide a framework for the beginnings of the tool being designed by the NPS project.

- 1.0 CMSP Decision-support system Interactive Chart (DSS IC)—The CMSP Decision-support system shall contain a comprehensive, and interactive map or chart with multiple layers that can be turned on and off as necessary.

Rationale:

This requirement may be somewhat obvious to those who have made use of ocean planning software before. It is necessary, however, because it sets the foundation for many of the other requirements. In fact, 11 of the 16 requirements are built on this foundation. This requirement addresses key variance 3, the access to historical data. Recall that such historical data is crucial to the formation of a draft EA or EIS. The decision-support system ought to provide simple, single-point access to all available historical data. Such a capability directly supports CMSP general functions 1, 2, and 3 by providing the template upon which data useful in planning and decision-making can be provided and used.

A single point of reference can support planners by helping aid in identification of potential ocean uses and resources. It can help ocean users by allowing for an integrated and comprehensive approach to planning. It can also help to reduce delays in planning and increases in the cost associated with permitting. This requirement also helps fulfill benefit 4 to the DOD number 4 by providing a hub in which DOD planners can identify areas for potential training.

- 1.0.1 CMSP DSS IC—Integrated NOAA Standard Nautical Chart. The CMSP Decision-support system chart shall integrate all data found on a standard nautical chart produced by the National Oceanic and Atmospheric Administration (NOAA) including, but not limited to: depth, aids to navigation, contour lines, lines of demarcation, and charted wrecks and obstructions.

Rationale:

Requirement 1.0.1 standardizes the type of charts used in the decision-support system and ensures they are compatible with the chart types used by much of the world. This requirement also addresses key variance 3 by providing historical data, such as charted wrecks and obstructions and bottom contours. The first two CMSP general functions are addressed because this requirement helps planners and regulators identify suitable areas for various uses. Once again, the benefit to the military lies in benefit 4. The military has access to both paper and electronic charts that are at least as detailed as any civilian use charts produced by NOAA. These charts, however, are not integrated with the geospatial data laid out in subsequent requirements. Including fundamental chart data assists the military by providing a context when reviewing areas for potential training uses.

- 1.0.1.1 CMSP DSS IC—Integrated NOAA Standard Nautical Chart Monthly Update. The CMSP Decision-support system charts shall be updated on a monthly basis for all data sets which such updates are available. (NOAA charts updated weekly).

Rationale:

Requirement 1.0.1.1 provides a maintainability requirement to support requirement 1.0.1. Charts receive continual updates; in fact, NOAA updates charts on a weekly basis. Updates can range from more detailed depth contours to newly-discovered or created wrecks to newly-laid submerged cables and pipes. This requirement supports CMSP and the military for all the same reasons as 1.0.1.

- 1.0.2 CMSP DSS IC—Integrated Ocean Current Vectors. The CMSP Decision-support system chart shall contain a publicly accessible web-based data portal with mapping and overlay capabilities with the mean and variance of oceanic current vectors for all available areas.

Rationale:

Requirement 1.0.2 addresses key variances 1 and 3. If adequate oceanic current vectors are available, this may reduce or eliminate the need for organizations planning ocean operations (for example, marine aquaculture companies) to pay the cost of gathering such data themselves. Many organizations operate within three nautical miles of the shore and require current data as close to their proposed operating sites as possible. Gathering current data often requires renting and expensive deployments of current meters and buoys. At a minimum, this requirement addresses key variance 3 by providing historical current vectors. Even if historical vectors lack detail, they may provide enough insight to rule out potential aquaculture sites, thereby saving the company time and money in the business planning and EA or EIS processes.

CMSP functions 1, 2, and 3 are all covered by requirement 1.0.2. This requirement provides simple and single point data access for agencies involved in the EA or EIS process that evaluate company models of ocean currents and the forecasted effects of fish waste on the local ocean environment. It also can help reduce permitting delays due to regulatory inefficiencies stemming from a lack of data common to all parties. Benefit 4 to the military is addressed in this requirement. Ocean currents can greatly affect navigational planning and inertial navigation equipment performance. Ocean current information may be gathered from a variety of places, but the efficiency gains of integrating it into the decision support system is hard to overstate in terms of navigational planning potential.

- 1.0.3 CMSP DSS IC—Integrated Culturally Significant Areas. The CMSP Decision-support system shall provide an integrated layer that maps all culturally sensitive areas.

Rationale:

Requirement 1.0.3 also addresses key variance 3. The location and types of culturally sensitive areas are critical to spatial planning in the Hawaiian Islands and other Pacific Islands. Such data is sometimes lacking. Indeed, one interview subject stated that many culturally sensitive areas are known only to locals and are not public knowledge. This can lead to great difficulties when working with the Office of Hawaiian Affairs for the EIS or Section 10 permit. It can also lead to a company being caught off guard during the public comment period during the EA process. Providing this data in the integrated decision support system would help minimize this variance.

All three CMSP general functions are addressed by this requirement. Of note, this requirement would likely have the largest impact on CMSP function 3 by reducing conflicts among ocean users. If a company has knowledge of cultural sites, they will likely work to place their operation in areas that are out of conflict with the sites. This requirement addresses benefit 4 to the DOD. Culturally sensitive areas are often misunderstood or unknown by the military. Knowledge of such sites can help military training planners prevent committing cultural fouls such as conducting weapons training in the wrong area.

- 1.0.3.1 CMSP DSS IC—Integrated Culturally Significant Areas. Description. The cultural sensitivity areas shall include a detailed description of the nature of the sensitivity and the impact on water space usage.

Rationale:

Requirement 1.0.3.1 contains all of the same inherent utility of 1.0.3 but adds a layer of functionality that may prove extremely valuable to planners on all sides of the permitting process. Culturally sensitive areas can range from sacred fishing grounds to ancient burial sites. Some types of areas may be considered off limits to all uses, while others may be compatible with some types of ocean uses. Detailing the type and nature of the area provides a level of robustness to the decision-support system that is currently lacking in the permitting process.

- 1.0.4 CMSP DSS IC—Integrated Layer of Threatened and Endangered Species. The CMSP Decision-support system chart shall include an integrated layer that outlines the habitat range of all threatened and endangered species.

Rationale:

This requirement addresses key variances 9, 12, and 16, which all pertain to agency response and review time. The potential impact on threatened and endangered species is an important part of all permitting considerations. If the CMSP decision support system integrates agreed upon habitat ranges for each of these species, some of the redundancies and inefficiencies in the process can be eliminated. It can also allow the company to preplan and anticipate the types of monitoring and emergency response plans that they will likely be responsible for. This clearly supports CMSP function number 2 with its emphasis on integration and proactivity.

Requirement 1.0.4 also supports DOD benefit 4. The military must abide by laws protecting endangered species, just as the general public. Interactions between military units and endangered species, especially marine mammals and reptiles, can occur both in the ocean and on the beach. The ability to place an endangered species layer on the decision support system chart could help military planners avoid such interactions.

- 1.0.4.1 CMSP DSS IC—Integrated Layer of Threatened and Endangered Species—Cross Reference. The threatened and endangered species layer shall include integrated access to monitoring and emergency response plans that have been previously approved by NOAA PIRO.

Rationale:

Requirement 1.0.4.1 supports 1.0.4 and addresses all of the same aspects of CMSP. It complements requirement 1.0.4 and adds to the comprehensiveness of the decision support system. This requirement may be of greatest benefit to the companies applying for a permit. Access to previously approved monitoring and emergency response plans may eliminate much of the labor and research time associated with developing such plans. A company would be able to take a plan that NOAA PIRO has previously approved, modify it to suit their specific situation, and receive a faster review process than would be the case without access to previously approved plans.

- 1.0.5 CMSP DSS IC—Leased Areas. The CMSP Decision-support system chart shall outline all areas currently leased or designated for various ocean uses including, but not limited to: mineral rights, energy generation, aquaculture, and non-classified military operating areas.

Rationale:

This requirement addresses key variances 9, 12, and 16. This requirement addresses the agency response and review time variances because it gives all stakeholders the ability to see what ocean uses are occurring and where they are located. Such a single source of use data apparently does not exist and would enhance the decision support system.

This addresses CMSP functions 1, 2, and 3. It can aid companies in reducing conflicts by providing more information about where to site their operation. It can also reduce environmental impacts by allowing all stakeholders to view the density of various ocean uses. This requirement also furthers the integrated, comprehensive aspect of the decision support system by providing even greater functionality. It can also reduce delays in planning and regulatory inefficiency by allowing all agencies to view ocean activities in their consideration of permit applications.

DOD benefits 4 and 5 are addressed by this requirement. With regard to benefit 4, this requirement gives the military the ability to easily see where different types of operations are taking place. This may assist military training by showing them areas to avoid or consider in the pursuit of real world training. Additionally, this provides companies with the ability to know where standard military training areas are located. Such locations are often not well known or accessible to the public and can derail a permitting process.

- 1.0.5.1 CMSP DSS IC—Leased Areas—Cross Reference. The outlined areas shall include integrated cross references and linked access to all publically available documents involved in past ocean use permitting including but not limited to: environmental assessments, environmental impact statements, leasing information, NDEPS permit documentation, Army Corps Section 10 permit documentation, and CDUP documentation.

- 1.0.5.2 CMSP DSS IC—Leased Areas—Updates. The outlined areas' documentation shall be proactively updated as documents are approved be the various permitting parties.

- 1.0.5.3 CMSP DSS IC—Leased Areas—Updates. The outlined areas shall be proactively updated with areas being pursued for a permitted use.

<u>Rationale</u>:

Requirements 1.0.5.1 through 1.0.5.3 support and complement requirement 1.0.5. They address key variances 3, 9, 12, and 16, which pertain to access to historical data and agency response and review times. All three requirements are intended to aid in streamlining the permitting process and should ultimately benefit both those pursuing permits as well as those reviewing and approving permits.

Requirement 1.0.5.1 and 1.0.5.2 provide an additional layer of functional capability and maintainability to the outlined leased or designated areas. These two requirements allow easy, single point access to the already publicly available documentation related to ocean permitting. These documents are generally scattered across the Internet and can be time consuming to track down. Such documentation supports those pursuing new or updated permits by providing information+ on relevant expectations, requirements, and processes. This information can improve efficiencies and reduce the costs and resource expenditures associated with obtaining a permit.

These requirements support CMSP function 3 by potentially reducing costs and delays from planning. They also ensure that the decision support system maintains ongoing usefulness. There may also be similar benefits to the military services, but it is unclear what specific process the military must go through to pursue ocean use permits, so these potential military benefits cannot be clearly determined.

Requirement 1.0.5.3 can be considered both a usability and a maintainability requirement. The PIRPB wants the decision support tools to provide a proactive approach to planning and managing (CMSP function 2). The basic usability of the tools is critical to providing a proactive approach and thus there is a need to create a requirement that ensures the lease and designated ocean spaces are updated as new companies, organizations, or the military pursue permits for ocean operations. This requirement will also help reduce potential conflicts by ensuring that two or more entities are not pursuing permits without knowledge of each other's plans. Thus this requirement also addresses CMSP function 3.

The DOD benefits overlap with CMSP benefits 4 and 5 from this requirement by providing "the Navy and DOD with information of other ocean uses" to be used in "siting training, natural resource permitting, selecting new training areas, and encroachment" (Griffin 2015). It also "provides visibility (non-classified) of DOD training and testing areas to other ocean users so that they can site their activities with reduced conflict" (Griffin 2015). This requirement builds on the parent requirement (1.0.5) and supports the reduction of conflicts between DOD and the public.

2. Decision-Support System Central Hub

The final four requirements deal with streamlining the permitting process. These recommended requirements are not intended to bind state and federal agencies to using a specific decision support system. These requirements do, however, support the development of a decision support system that would support the work of the agencies, PIRPB, the public, and others involved in CMSP, ocean use permitting, and leasing.

- 1.1 CMSP—Decision-support system Central Hub (DSS CH). The CMSP Decision-support system shall have the ability to act as the central hub for permitting paperwork.

Rationale:

This clearly addresses key variances 9, 12, and 16, which all relate to agency response and review times. The decomposed FFBDs showed that the marine aquaculture permitting process involves many federal and state agencies, with no central repository for documents concerning reviews, approvals, disapprovals, updates, rebuttals, feedback, public comments, and questions and answers. The role network results indicated that agencies generally do not consult or communicate with each other in meaningful ways during the permitting process. This requirement, and the three that follow, address these issues.

- 1.1.1 CMSP DSS CH—Transparency. The CMSP Decision-support system permitting central hub shall be publically viewable.

Rationale:

Requirement 1.1.1 provides a layer of transparency to the public and could eliminate the need for hard copies of the draft EA to be distributed around the state. Clearly, this would directly reduce the cost to the company and therefore has the added benefit of addressing key variance 1.

- 1.1.2 CMSP DSS CH—Publically Accessible (Cloud Based). The CMSP Decision-support system permitting central hub shall allow all parties involved in permitting to securely upload permitting related documents throughout the permitting process.

Rationale:

Requirement 1.1.2 complements requirement 1.1 by minimizing or eliminating the need for hard copy documentation, faxes, and emails between companies, agencies, and others.

- 1.1.3 CMSP DSS CH—Publically Accessible (Cloud Based). The CMSP Decision-support system shall provide cataloged access to all publically available documents involved in past ocean use permitting including but not limited to: environmental assessments, environmental impact statements, leasing information, NDEPS Permit documentation, Army Corps Section 10 permit documentation, and CDUP documentation.

Rationale:

A decision support system that provides a library of cataloged documentation for all levels of permitting for all manner of ocean uses would provide substantial benefits to all organizations and individuals involved in ocean use permitting and leasing. These benefits would occur mainly by reduce resource expenditures and increasing efficiencies in communications. Note that requirement 1.1.3 is different from 1.0.5.1 in that it is not necessarily linked to the chart but rather to a searchable library or database. Thus, a user in search for several examples of NPDES paperwork could quickly gain a plethora of past examples rather than hunt around the interactive chart.

Requirements 1.1 through 1.1.3 provide clear benefit to the CMSP effort. Two noted experts in the field of marine policy have stated that "stakeholder participation and involvement in the [marine spatial planning] process should be early, often and sustained throughout the process" (Pomeroy and Douvere 2008). Requirements 1.1 through 1.1.3 address these needs. They address CMSP functions 2 and 3 by streamlining the permitting process. The creation of a decision support system that also acts as a hub for permitting would also help ensure that: (a) the system is integrated at all levels of state and federal permitting; (b) the system is comprehensive and flexible; and (c) stakeholders can use the system to proactively plan and manage. The decision support system also provides tools for reducing inefficiencies in the permitting process. Finally, the requirements may prevent the potential loss of critical economic opportunities, which could benefit not only the state but the nation as more companies may be incentivized to pursue permits.

The recommended requirements also address key variance 1, the assessed cost of permitting operations. This variance, like many kinds of variances in many different contexts, results in great part from uncertainties about the permitting process. If a company cannot accurately forecast, time, labor, travel, and other resources, then they cannot wisely allocate one of their most important resources; their capital. Thus, they may overestimate and tie up capital, or underestimate and take on undue risk. Improvements in the permitting process can reduce the uncertainties, which should lead to more accurate forecasts and therefore more accurate capital allocations. Consequently, all of the requirements may be considered to impact or indirectly address key variance 1. Key variance 1 is not listed for each requirement though because the impacts may be indirect.

VI. ADDITIONAL BENEFITS TO DOD

While outside the scope of the preceding requirements discussion, there are two final benefits to the military service, as defined by the CMSP PIRPB (Griffin 2015). These include benefits 1 and 2. Benefit 1 says that CMSP will “further the National Ocean Policy as directed, by assisting in the development of the regional plan.” The implication here is that the military will assist in the development of the regional plan. Benefit 2 states that “officers develop stakeholder engagement skills outside of the Navy, in the community.”

During the course of this research, the author, a naval officer, was able to participate in both benefits 1 and 2. A major objective of this thesis, and the entire NPS CMSP project, is to assist in the development of a regional plan for the Pacific Islands and for a related decision support system. This system would, in turn, support improved planning and managing of ocean spaces and uses, including DOD uses.

The author benefited from the interaction with actual companies who operate and do business in the state of Hawaii. The interviews and data gathering conducted while performing this research included engaging with representatives of three aquaculture companies. These are some of the stakeholders that CMSP is intended to impact in a positive way. The skills and knowledge gained will benefit this officer and the others who participate in the NPS efforts.

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VII. FINAL REFLECTIONS

It would be remiss to fail to provide a brief reflection on the limitations of this research and analysis, how it could have been done better, and ideas for further study. Surely, such reflection provides a key road to future improvement both personally and for the NPS efforts at large.

This analysis would have benefited from additional interviews. More interviews would generate a bigger data set and thus a more robust content analysis. Only three companies were willing to provide participants for formal interviews. This seemingly low recruitment is likely due to two factors. First, there are a limited number of aquaculture companies operating in Hawaii; a fact likely attributable to the problems with permitting identified during the conduct of this research. Second, the requirements and wording of the necessary Institutional Review Board (IRB) agreement may have caused some potential or otherwise willing subjects to decide against participation. Indeed, the formality and worst-case mentality of the wording of IRB consent forms and recruiting protocols can seem intimidating, especially when the researcher is working on behalf of the government.

Of the three interviews that were conducted, the biggest area of potential improvement lies in the flow of the interview discussion. It is likely naïve to assume that a particular question will elicit a simple, or binary response, especially when investigating a confusing process such as aquaculture permitting. However, room may exist to improve question wording in such a way that responses would elicit more orderly and less wandering answers. This is not to discount the interviews that were conducted or the value of the data they provided. Rather, it is to say that the content analysis and data mining were complicated by the lack of perfectly orderly question responses. Thus, key data points were not necessarily located in response to a particular question and the entire interview needed to be thoroughly considered for all data points. Improved question wording will never completely solve this problem but may help minimize it.

Finally, future NPS efforts in the CMSP project may want to consider two areas. First, it might prove valuable to conduct a similar study from the government perspective. Due to the sheer number of agencies involved and their scattered physical presence, this area of potential future study may require multiple researchers. The value of such a study lies in the investigation and findings of what the government needs out of a decision-support system. There may be laws, policy, or habits of certain agencies that dictate additional or modified requirements relating to the decision-support system. Such knowledge would certainly prove invaluable to system design and implementation.

Second, a follow-up study of the form conducted here may help ascertain the actual utility of the decision-support system, in whatever form it eventually takes, to the companies it is intended to serve. Such a study would need to be reserved for several years into the future when the tool has been developed, tested, implemented, and used for some time. The findings of this study could help continually improve the tool and fulfill the ultimate goal of CMSP, which is to improve management of the ocean and near coastal spaces.

APPENDIX A. IRB RECRUITMENT PROTOCOL.

IRB Recruitment Protocol
Tyler McDonald
4/21/16

Hello,

My name is Tyler McDonald and I am a graduate student at the Naval Postgraduate School in Monterey, CA. I am currently investigating aquaculture company permitting processes and how they might inform the construct of the recently begun Coastal Marine Spatial Planning (CMSP) initiative in the Pacific Islands. As you may or may not know, the CMSP Regional Planning Body has recently started meeting in order to begin the work of coming up with a comprehensive planning tool for defining and allocating ocean resources.

This research will examine the specific process by which a typical aquaculture company gathers relevant information for use in coastal marine spatial planning, and applies for and obtains a permit to operate. In this research, I will use a systems engineering perspective to analyze and recommend improvements to the ocean aquaculture planning and permitting process for Hawaii.

Your participation in this research, as a subject matter expert in aquaculture, is requested. You would be interviewed by me, as the primary student researcher, about the permitting process used in your organization. I anticipate the interview will take 1–1.5 hours, and request that the interview be conducted at your workplace. Interview questions can be provided to you ahead of time if you request them. Also, if possible, I would like to observe you completing any tasks related to the permitting process while at your workplace. The time spent on these observations is completely at your discretion.

I intend to audio record the interview to help facilitate data analysis. No names or personal information will be asked for during the course of the interview(s) and therefore will not be recorded. All audio will be transcribed and any identifiable data will be deleted from the transcript. Audio files will be maintained on a media device that is kept in locked storage at the Naval Postgraduate School. Interview transcripts will be maintained in electronic format on a password protected server.

Results of the analysis of this data will allow me to generate recommended requirements for the CMSP RPB to integrate into their decision making tool(s) for coastal permitting. These recommendations will be aimed at improving the process from the company's perspective. At the conclusion of my work I will provide copies of the thesis to you and your organization.

I anticipate being in Hawaii from the 22nd to the 29th of May. If you are interested in participating in this study, please reply to this email with a day and time that best fits your schedule to meet with you. Attached is a copy of the Informed Consent Form you will be asked to complete, if you agree to participate. Please review it and let me know if you have any questions.

Also, if you happen to know someone else who may be interested in participating in this research, then please feel free to forward this to that individual or have them contact me directly.

I can be reached at the following: tbmcdona@nps.edu. If you have any questions or comments about the research, you may also contact the Principal Investigator, Dr. Karen Holness, 831–656-2631, kholness@nps.edu. Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Chair, Dr. Larry Shattuck, 831–656-2473, lgshattu@nps.edu.

I look forward to hearing from you in the near future.

Thank you for your consideration,
Tyler McDonald
tbmcdona@nps.edu

APPENDIX B. INTERVIEW QUESTIONS

Knowledge Elicitation Interview Questions:

1. Permitting Scenario.

    a. Describe a typical permitting scenario that either already happened or is currently in progress.
        i. What is/was the permit for?
        ii. To do what exactly?
        iii. In what location?

2. Environment. With regard to obtaining a permit:

    a. Who are the stakeholders (people, agencies, organizations) that your organization interacts with?
    b. How influential are each of those on your organization? In other words, how much say do they have on how you conduct operations?
    c. What does your organization need or want from each of these stakeholders?
    d. Why does the organization want that?
    e. What do you think each stakeholder wants or needs from your organization?
    f. Why do you think they want that?
    g. Are there any other factors from outside of your organization that can impact your ability to obtain a permit?

3. Detailed Tasks.

    a. What are the basic tasks you need to do in order to apply for a permit?
    b. What is the typical order of these tasks?
    c. For step #X, please describe the following:
        i. Who is typically involved this task? What is each person's primary job function?
        ii. What is typically needed in order to successfully complete this task? What information? What else?
        iii. How do you get these items?
        iv. How long does it normally take to get them?
        v. What kinds of things can impact your ability to get these items?
        vi. What exactly do you do with each item once you get them?
        vii. What software do you use to complete this task?
        viii. Do you use any other equipment (e.g., scanner/copier, etc) to complete this task?
        ix. What kinds of things can impact your ability to complete this task?

1. How do you usually handle these impacts if they occur?

x. How long does it normally take to finish this particular task?

xi. What are the results or end products of this task? What do you do with them?

4. Key Factors.

a. Earlier you described factors that impact your ability to complete each task in the permitting process.
   i. Rank each factor with the most significant at the top and least significant at the bottom.
   ii. Explain why you ranked them in this order
b. For the factors that are of greatest concern can you describe:
   i. What you think should be done to address each factor?
   ii. Who you think should be involved in addressing these factors?

5. Process Redesign.

a. If you had the opportunity to redesign the permitting process:
   i. What would you change?
   ii. What information, software or equipment would be needed?
   iii. Who would be involved?

APPENDIX C. CONTENT ANALYSIS CLUSTERING OUTLINE

Process:

1. Create a Business Plan

2. Scoping Meeting with all Permitting Agencies
   - Present plan/outline
   - Generally closed to the public

3. Environmental Assessment (EA)
   - “Finding of no significant impact” required prior to Conservation District Use Permit (CDUP) being issued
   - Public review w/comments and responses
   - Historical assessment data
   - Modeling (3rd party)
   - Impact estimates
   - Current meter (requires permit)
   - Federal Agency review
   - NOAA (endangered species, fishing reports, marine mammals, essential fish habitat, seabirds)
   - Ask same questions even if answered by previous permit
   - U.S. Fish and Wildlife Service
   - Federal Aviation Administration
   - State Agency Review
   - Dept. of Agriculture
   - Dept. of Health

4. Environmental Impact Statement (EIS)

- All steps of EA
- Cultural impact statement
- Hired 3rd party firm ($1M)
- 1 year to complete
- Send copy (~1000 pgs) to every newspaper and put in every library
- Write letter of response to all persons who provide comments
- Submit approved EIS to DLNR

5. National Pollutant Discharge Elimination System (NPDES) Permit—Environmental Protection Agency (EPA)

- NOAA reviews
- Good for 5 years
- EPA allows State Dept of Health to review the NDP
- 6 to 14 month approval
- Some requirements influenced by NGOs and fear of lawsuits

6. Army Corps Section 10 Permit for anchoring

- Same NOAA agencies as before
- Four permits rolled into one
    - NOAA endangered species
        - monitoring and emergency response plans for all endangered species in the area of operations
    - -NOAA benthic habitat
    - -Office of Hawaiian Affairs (looking for disturbance to historical sites)
    - -Coastal zone management plan (CZMP)
        - Federally required plan that is managed by State department of business and economic development (ensures you have all the other permits)
- Some requirements influenced by NGOs and fear of lawsuits

7. Conservation District Use Permit (CDUP)

- 5-year renewal
- "Primary permit for operating offshore"
- Ceded (Native) lands (out to 3NM)
- Approved by DLNR board

8. Lease

- State appraiser determines lease amount
- No comps for comparison
- Sign a lease (time varies)

9. Begin Commercial Operation

Stakeholders Listed:

State of Hawaii

- Department of Land and Natural Resources (DLNR)
- Division of Coastal Conservation and Lands (OCCL) – State Coordinating Agency for CDUP
- Division of Boating and Recreation (DOBR) (advisory only)
- Department of Health (Clean Water Branch)
- Department of Agriculture
- Department of Economic and Business Tourism
- Department of Transportation (airport – works with FAA)
- Office of Hawaiian Affairs

Federal

- NOAA PIRO
- Army Corps of Engineers
- Fish and Wildlife Service

- Coast Guard (advisory/informal)

Trusted Experts/State consultants

- University of Hawaii
- Hawaii Institute of Marine Biology
- Hawaii Pacific Oceanic Institute
- Grant Organizations

Public

a) Public information meetings
    - Chamber of Commerce
    - West Hawaiian Fisheries Council
    - Fishing Groups
    - Outrigger Canoe Groups

b) Anti-aquaculture activism
    - Food and Water Watch
    - Nature Conservancy
    - Native Hawaiian groups
    - Environmentalists

c) World Ocean Council

Agency Desires:

Data:

- Volume of fish produced
- What are you doing?
- How does your operation restrict other ocean uses?
- Discharge profile
    - How much?
    - Water quality effects?
    - Benthos Effects?

Timeline:

- 1 year
- 2 years
- 3 years

Equipment Required:

- MS Office (word, excel, powerpoint)
- Boats
- Current meter rental
- Water and benthic sampling equipment

Roles within the Company:

- Upper management—coordinates/presents/schedules (Primary and central permitting person within the company), does everything with paperwork
- Biologists/Oceanographers—collect and process data

Variances:

Table 6 contains a list of variances that were identified from the interview data.

Table 6. List of Variances

Number	Variances
1.	Assessed Cost of Permitting Operations
2.	Number of Participants
3.	Access to Historical Data
4.	Cost of 3rd Party Modeling
5.	Need for Oceanic Current Data
6.	Results of Oceanic Current Analysis
7.	Volume of Public Comments
8.	Agency Response/Review Time—EA
9.	Travel to HNL for Coordination
10.	Prevalence and Significance of Cultural Sites—EIS
11.	Agency Response/Review Time—NPDES
12.	Number of Monitoring Plans Required
13.	Prevalence and Significance of Cultural Sites—Sect 10
14.	Volume of Feedback
15.	Agency Response/Review Time - Sect 10
16.	DLNR Board Responsiveness/Review Time
17.	Assessment Value

Redesign Suggestions

- Have a coordinating group or person (with knowledge of aquaculture and some weight behind them).
- Fix/overhaul discharge permit (currently based on sewage outflow).
- Streamlined or fast-tracked process
- Provide a method for a research permit that is fast-tracked based on small scale as compared to commercial sized operations.
- No new agencies or laws (instead, use just Magnuson-Stevens Fishery Conservation and Management Act)

- Pre-approved zoning and uses (there is no way for a company to know if an area is used by military, shipping, minerals, etc.)

- Provide a way for the large number of independent agencies to talk to each other and work together. They currently operate at their own pace in their own sphere with no regard to other agencies or the organizations they are serving.

- Make the EA/EIS the core document that all rely on.

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