A SYSTEMS APPROACH TO ASSESSING THE ENVIRONMENTAL IMPACT OF BUNKERING OPERATIONS IN PORTS

DINWOODIE, John, *School of Management, University of Plymouth Business School, UK*

SUN, Xiang, *School of Management, University of Plymouth Business School, UK*

KNOWLES, Harriet, *Falmouth Harbour Commissioners, Cornwall, UK*

TUCK, Sarah, *School of Management, University of Plymouth Business School, UK*

BENHIN, James, *School of Management, University of Plymouth Business School, UK*

ABSTRACT

This paper appraises the usefulness of a framework which is accessible to port authorities to assess the potential environmental impact of bunkering operations. Increasing numbers of ship movements generate more frequent routine bunkering operations in ports but few formal approaches exist for assessing their environmental impact, which potentially, could be significant. A systems approach highlights inputs and outputs that define processes in the environmental assessment, identified in a process modelling technique. At a strategic level, primary processes are defined which affect the environmental assessment of present and future bunkering operations and their potential impacts. Later, tactical service processes define the integrity of processes that guarantee service level and quality. Finally, operational processes define outputs. This approach facilitates planning of more sustainable bunkering operations in ports. A case study is based on Falmouth Harbour Commissioners (FHC) which regulates much of Falmouth Harbour and hosts the UK's largest offshore marine bunkering operation. The approach proceeds by defining the local problem, system boundaries and function and variable flows, and identifying strategic, tactical and operational processes undertaken in the environmental assessment. Falmouth has recently recorded a three-fold rise in the number of vessels calling, and a 50% rise in the volume of fuel sold as more vessels take onboard low-sulphur fuel for use in the English Channel and other EU designated Sulphur Oxide Emissions Control Areas. The systems approach which empowers FHC to mitigate potential risks and assess development proposals pro-actively is easily transferable to other ports.

1. INTRODUCTION: MARITIME OPERATIONS IN UK PORTS

In topological network representations, sea-land interfaces in maritime transport systems are typically represented as simple nodes. However, modern ports offer value adding logistics services as complex centres which operate within integrated logistics networks (Notteboom and Rodrigue, 2005). International supply chains have dramatically increased the range and complexity of maritime operations demanded in ports, thereby increasing the risk of adverse environmental impacts and complexity of the regulatory framework required to manage them. In turn, UK and other port authorities face increasing legal requirements, stakeholder pressures and increased administrative burdens to ensure compliance. To assist them, this paper proposes a systems framework within which to plan assessment of the potential environmental impact of routine bunkering operations which are subject to specialist regulations, conventions and guidelines in addition to environmental legislation which guides port authorities. To comply with this demanding agenda requires time and cost resources which stretch most ports, but all parties benefit if proactive engagement can extend beyond compliance.

As host to Europe's largest ports sector (Oxford Economics, 2009), the UK included 650 statutory harbour authority ports handling 573Mt of freight embracing 95% of national imports and exports by volume and 75% by value in 2004 (Department for Transport, DfT, 2006,1). The UK government seeks to promote high environmental standards and support sustainable port development (DfT, 2000). However it does not intervene in commercial activities, charging port authorities with a statutory duty to meet social and environmental obligations whilst embedding corporate social responsibility (CSR) concepts in their management systems and undertaking routine operations and development projects commercially (Pettit, 2008). "Environmental assessment" does not imply monetary or quantitative evaluation of potential impacts but experts may need to assess whether potential impacts are likely to be "significant", depending on the scale of projects, local environmental sensitivity and complexity of impacts (Paipai, 1999). Port developments that generate environmental concern are subject to Environmental Impact Assessment (EIA) methodologies (Darbra *et al.*, 2005) to assess the potential impact on marine and terrestrial habitats (UNESCAP, 2009). Where assessments identify adverse impacts, mitigation requires management plans to conserve and protect public access to features of natural beauty or historic interest. Public bodies and harbour authorities prepare these for Sites of Special Scientific Interest (SSSIs; DfT, 2000). A qualitative scoping study is required if developments will impact *inter alia* on biodiversity or water (DfT, 2002).

Environmental standards for port operations are notified to port authorities to ensure that standards, guidance and best practice are widely available and assist compliance (DfT, 2000). EC Directive 85/337 advises all major industries including ports, to conduct an environmental audit covering *inter alia*, handling and storage areas of prescribed materials, waste emissions, spoil disposal areas, fishing, wetlands and zones of specific scientific or cultural interest. This directive exhorts prioritization of issues for environmental protection and compliance with conventions and codes covering marine pollution and dangerous goods. Environmental audits are discretionary, but port managers are liable for environmental damages with consequent punitive damages. Port managers have influenced legislation as consultation and agreement underpin guidelines and best practice, supported by requirements to protect and manage nationally important sites. Practitioners have contributed to benchmarks, initiatives, projects, management schemes, training, monitoring, research and collaborative involvement (Paipai, 1999) and the British Ports Association (BPA, 2009) Environmental Code of Practice (ECP) aimed to raise environmental awareness amongst port employees and users. Government intervention is limited to statistical information, general guidelines, control on the development planning process and rules for project appraisal and commercial independence (Gilman, 2003).

This paper briefly reviews some extant tools to assist environmental management in ports and aspects of offshore marine bunkering including marine fuel oil, bunkering regulations and procedures. Next, because complex maritime operations may increase the perceived risk of untoward events and stimulate environmental concerns, the systems approach and applications of it to bunkering within the environmentally sensitive case context of Falmouth Harbour are introduced. Processes at strategic, tactical and operational level are analysed and the usefulness of the systems approach to the port authority is appraised.

2. ENVIRONMENTAL MANAGEMENT AND OFFSHORE MARINE BUNKERING SERVICES

2.1 Tools to aid environmental management in ports

Intra-firm development of environmental awareness is a process which involves understanding of corporate environmental impacts and management of them (Hannon and Atherton, 1998). At any one time, individual organizations are at different stages of both. Some early work investigated environmental management practice in ports, aiming to develop effective Environmental Management Systems (EMS) to assist ports to manage environmental risks successfully and improve their performance. A case study of three Fal estuary ports which established a joint EMS changed managers' awareness (Paipai, 1999, 45). Later, ongoing pursuit of continuous improvement engendered new approaches in which larger ports have shifted from investigating the need for environmental management to deploying tools and methodologies to encourage better performance, such as those embodied in the EcoPorts project (EcoPorts, 2006). ISO14001 (Saengsupavanich *et al.*, 2009) promotes continual improvements by encouraging EMS adoption and implementation. These systems and standards assist firms to systematically develop a formalised management process, and evaluate the effectiveness of their activities, operations, products, and services, but the specialist resources and sustained involvement required exceed the means of many ports. Likewise, so does continuous monitoring which improves understanding and assists risk management, supported by appropriate data collection techniques and record keeping (Darbra *et al.*, 2009). Multi-site applications of standardised procedures within Associated British Ports which identify environmental issues and their associated risks before ranking each by significance, assessing the probability of occurrence and magnitude of consequences (Darbra *et al.*, 2005, 867) offer scale economies which elude many ports.

The EcoPorts Foundation aims to help develop practical solutions for ports seeking to improve their environmental performance and to share knowledge and expertise *"to create a level playing field by limiting poor environmental practice as a competitive factor between port administrations"* (ESPO, 2003, 8). Initiatives demonstrate that larger ports can self regulate and EcoPorts offers an intermediary between the EU and ports on environmental issues, but many ports are not members. EcoPorts tools for environmental management assist ports to develop an Environmental Management and Information System to plan and assess environmental issues, monitor compliance and assess impacts. At entry-level, a Self Diagnosis Method (SDM) aims to identify environmental risks and establish priorities for action and compliance (Darbra *et al.*, 2004). A port manager can quickly complete a simple checklist, pay a fee, receive benchmark guidance on the port's environmental performance, an analysis report showing its strengths, weaknesses, opportunities and threats, and strategic advice. However, because the analysis is exogenous the port manager's understanding, awareness and commitment may be reduced. Over time, updated past comparisons of performance allow for progress reports to build evidence of the effectiveness of environmental management policies. A Port Environmental Review System (PERS) assists ports to implement an EMS through developing components of it. Measurement of environmental performance is possible through an independent review which consists of guidelines and example documents, but this requires time, incurs costs and being external, may deter internal commitment to its findings. Finally, a Strategic Overview of Environmental Aspects (SOSEA, Darbra *et al.*, 2005) identifies "significant" environmental aspects which stem from operations and guides a port in gathering information to manage its liabilities and responsibilities. This assists long term environmental strategic development, by highlighting the current situation and policies, thereby strategically increasing a port's environmental awareness. If a port attains ISO14001, additional demanding certification in the Eco-Management Scheme and Audit Scheme (EMAS) requires preparation of an environmental review and environmental statement.

Reporting of business processes in ports and how ports develop environmental awareness is either rare (Peris-Mora *et al.*, 2005) or omitted (Darbra *et al.*, 2004, 2005). Further, if ports do not fund membership of EcoPorts or employ personnel with environmental expertise these tools are inaccessible. Although Van der Veen (2006) reports SEM testing by 100 ports across Europe and PERS certification of 25, these initiatives have so far not embraced many UK ports. The depth of an initial SOSEA assessment is also limited. It proceeds by indicating whether each of 12 environmental aspects applies to a range of listed activities which include bunkering. Environmental aspects include *inter alia* emissions to air, soil and sediments, discharges to water, noise, waste production, changes in terrestrial habitats and marine ecosystems. An aspect is considered "significant" if either, after the number of ticks has been summed for each aspect, the number against it exceeds half of the maximum number of ticks recorded, or, if a breach of legislation is considered "significant". For each significant aspect, further questions relate to how it is managed and what environmental actions have been taken (Darbra *et al.*, 2005).

2.2 Marine fuel oil

Historically, bunkers stored coal in coal fired vessels. Typically, in heavy fuel oil (HFO) powered ships bunkers store residual low grade fuel oil. Crude oil distillation produces residues including hydrocarbons which boil at higher temperatures than gas oil, and remain after more valuable products have been removed. Grading of HFO reflects its viscosity together with sulphur content, or its distillate content, related to the energy in it. Further, because the viscosities and sulphur content of crude oils vary, the yield of residues suitable for producing marine fuel oil, vary. The quality of marine fuel oils affects ship handling, engine operation and quality parameters and high sulphur fuels are priced lower and although more corrosive, have been historically popular (Alizadeh and Nomikos, 2004, 284). Shipping companies, concerned with the quality and quantity of fuel oil consumed by vessels typically deploy fuel oil management programmes which determine the quality and quantity of fuel oil demanded.

In 1978 a 1973 International Convention for the Prevention of Pollution from Ships was modified by Protocol, creating MARPOL 73/78. In 1997, Annex VI, Regulations for the Prevention of Air Pollution from Ships, was adopted by the International Maritime Organisation (IMO). Enforced in May 2005, Annex VI regulated the mass/mass of sulphur content for marine fuel oil to control sulphur oxides (SOx) emissions from ships (IMO, 2009a). This will reduce to 0.5% by 2020 to 2025 (Table 1) with lower limits in SOx Emissions Control Areas (SECAs) in the North Sea, Baltic Sea and North America. These areas can cost-effectively cut ship-originated air pollution (Wang and Corbett, 2007). The maximum permitted sulphur content of marine gas oil and distillate fuels under EU Directive 1999/32/EC is 0.2% and for marine gas oils used within UK waters, 0.1% (UK P&I Club, 2008a). Ongoing demand for marine fuel oil coupled with IMO intervention will increase competition between suppliers and exaggerate quality variations. In 2004, distillates with >0.5% sulphur residual comprised 28% of a 305Mt market otherwise dominated by <4.5% sulphur residual (Robinmeech, 2009). By 2025, a 470Mt distillate-dominated market will comprise an 8% share for <0.1% residual, 82% for <0.5%, 4% for >0.5% and 6% for <3.5% maximum residual.

Table 1: IMO requirements on sulphur content in 2020 to 2025.
Source: Adapted from IMO (2009a)

Date	**Maximum % of sulphur**
Globally	
2009	4.5
2012	3.5
2020-2025	0.5
In Special Emission Control Areas	
2009	1.5
2010	1.0
2015	0.1

2.3 Bunkering operations and regulations

Bunkering involves the transfer of liquid hydrocarbons for propulsion or lubrication purposes and operations can include a pipeline connecting shore facilities, often a tank farm, to ships berthed at a jetty; supply via a specialist bunker vessel or simple barge; fuel transfers using road tankers. Offshore marine bunkering, the focus of this study, requires specialist techniques to prevent pollution and avoid potential leaks of residue from bunker hoses when disconnecting from receiving vessels. Experienced human resources are essential and in offshore operations, barge allocation decisions demand experienced engineers (Chang and Chen, 2006). Marine oil spillages are well documented (Talley, 1999) and although historical analysis indicates that tanker vessels generate similar accident rates to other vessel types, tank barges generate more spills (Talley et al., 2001). Bunkering operations must comply with MARPOL73/78 regulations (Lloyds Register, 2005) and Safety of Life at Sea (SOLAS) Conventions (IMO, 2009b) and codes regulating safety and environmental aspects of goods and ships guide marine fuel oil delivery. Conventions restrict and regulate discharges of oil and oily materials. Safe bunkering is covered by regulations on delivery barges exceeding 150 Gross Tonnes which must carry a Shipboard Oil Pollution Emergency Plan. If an oil spill or scenarios specified by MARPOL relating to preventing oil pollution arising from accidents occurs, this document conveys instructions from ship owner to master on how to act. ISM Codes (IMO, 2002) categorise bunkering as a critical operation which must be carefully planned, coordinated and cooperated with all parties involved from the point of ordering until delivery is completed (Steamship Mutual, 2008).

Oil terminals must ensure that both direct and indirect fuel oil transfers are safe and supported by preventative measures, controls and systems to guide ship-shore transfers. All vessels carrying oil and fuel must comply with national and international rules and regulations (Fisher and Lux, 2004). In oil terminals or ports, the duty officer checks that vessels, crews and safety systems comply with mandatory IMO instruments. Port or terminal managers use risk assessment and analysis to devise a Safety Management System (SMS) which details preventive, mitigating and recovery plans spanning safety, pollution, and fire. A Marine Terminal Operating Manual addresses navigational access, port channels for communication between ships and terminals, berthing procedures, pilot access, port access, procedures in emergency situations, loading and unloading procedures, documentation, equipment, terminal personnel and vessel responsibilities and duties (Fisher and Lux 2004).

Bunkering equipment includes transfer arms, access towers, valves, pumps, flanges, meter systems, fenders, mooring hooks, hoses, pipelines and electrical systems. Because equipment failure could cause an unsafe situation or pollution accidents, a system of survey, maintenance and certification for all equipment is maintained using preventative and planned maintenance systems. A holistic SMS highlights checks prior to operations, during cargo handling and pre-departure. Each scenario examines terminal facilities and loading arms, vessels, personnel on shore, crews on board, preventative maintenance systems, fire fighting systems, means of communication, weather conditions, and mooring systems. The ship or terminal SMS guides all bunkering operations and all assessed risks must be "reasonably" addressed in operational procedures although local definitions of "reasonable" may vary. ISM Codes (IMO, 2002) require every vessel to have safety procedures in place. Before commencing, all equipment, flanges, means of communication, loading rates, hoses and scuppers must be checked. During bunkering operations, all personnel on board assigned to these duties must engage solely in them.

To prevent oil losses requires planning and vigilance. Each vessel SMS must incorporate and ensure effective implementation of a recognised oil transfer procedure to ensure that bunkering operations are completed safely to minimize adverse risks to the marine environment (Steamship Mutual, 2008). An SMS is required for all offshore bunkering parties and terminals and all responsible persons and vessels must comply with SOLAS and ISM Code requirements. The SMS promotes safe practice in ship operations and a safe working environment to safeguard against all identified risks and improve the safety management skills of personnel onshore and aboard.

2.4 Bunkering procedures

Terminal managers and masters of vessels and barges taking bunkers or supplying fuel jointly seek to eliminate human error and operational incidents. Suppliers strive for safe operations and ship owners endeavour to receive good quality fuel oil. IMO and International Safety Guide for Oil Tankers and Terminals (ISGOTT) checklists to ensure safe bunkering operations address safety issues pre-transfer, during bunkering and ship-shore operations (Helcom, 2009; ICS, 2006). Procedures indicating the actions required are supplemented with crew training (Videotel, 2009). Locally accepted standards to guide fuel oil transfer procedures include the Singapore Bunker Procedure (SSA, 2009), American Society for Testing and Materials protocol (ASTM 1993) and ISO/FDIS 13739 (ISO, 2009). Use of checklists and adherence to predetermined routines can minimise and safeguard against errors. Table 2 typifies procedures from a delivering vessels' perspective.

Table 2 Bunkering procedures from a delivering vessels' perspective

Stage	Action
Prior to commencing taking bunkers	Bunker suppliers issue a written statement on the Bunker Delivery Receipt to indicate viscosity, density, water content, flash point and fuel delivery temperature for volumetric quantity calculations. Charterers' port agents and bunker suppliers conduct representative bunker sampling. Send results to a receiving vessel which needs to test the quality of bunker fuel oil. If not received, the receiving vessel master issues a notice of protest. Complete all pre-loading checks. Verify that all communication systems are effective.
During bunkering	Check loading rate frequently
Before changing tanks	Ensure that excessive back pressure is removed from the hose or loading lines
Before topping-off tanks	Reduce the loading rate to decrease the possibility of air locks in the tank causing mist carry over through the vents and risks that the supplier might not stop quickly enough.
Loading process is complete	Drain all hoses and tanks back to the tank or barge prior to disconnection. Beware of blowing lines with air into overfull bunker tanks.

The environmental concern with bunkering operations is such that if vessel refuelling results in spills, it affects water and sediment quality, human and wildlife health, fisheries and recreational pursuits, and potentially food chains serving entire marine ecosystems if persistent toxic elements become stored in sediments (EcoPorts, 2006). Ships which burn fuel oil produce sulphur oxide emissions and chemical wastes promulgating IMO to promote exclusion of any chemical waste from fuel oil. If oil spillages and leakages arise during bunkering operations, pollution harms the marine environment and is costly to clean up. Human error underpins most overflows and spillages (ICS, 2006) but few pollution incidents are predictable and significant claims arise from spillages attributable to insufficient awareness of defined procedures or failure to follow them. Occasionally, external factors impinge on vessel operations to promulgate fuel escapes through air vents in bunker tanks (Steamship Mutual, 2008). Table 3 lists some actions to prepare for offshore bunkering.

Table 3 Preparing for offshore bunkering operations

Actor	Action	Risks
Bunker supplier	Ensure adequate quality of marine fuel oil supplied	Damage to ships' engines Environmental impact of seagoing ship emissions
Bunker supplier	Use approved techniques for handling	Leaks and spillages of residue
Port authority	Apply a systematic Environmental Impact Assessment (EIA)	Unaware of potential environmental impacts
Port authority	Set objectives and targets to improve implementation	Non-compliance Increased likelihood of adverse environmental impacts
Port authority/ terminal manager	Seaport or oil handling facility oil pollution emergency plans	Unprepared to counter potentially significant environmental impacts

3 METHODOLOGY

3.1 The systems approach

Despite early interest in applying the concepts of General Systems Theory which emanated from scientific origins in biology and the physical sciences, to management studies (e.g. Kast and Rosenzweig, 1972; Churchman, 1979), applications of management systems to the management of scientific processes and evaluation are less frequent (Pidd, 2004). Recent applications of systems theory in a maritime context tend to focus on areas such as organisational effectiveness at seaports (Cetin and Cerit, 2010) and exploit the conceptualisation of ports as open systems which interface with the complex dynamics of international trade, supply chain systems and technological change. Typically, the conceptual formulation attempts to define a system comprised of a holistic unit made up of components;

flows between them and with the system's environment, of mass, energy and information; and the system's functional purpose. Churchman's (1979) emphasis on identifying system objectives and performance measures; system resources; the system's environment; the activities, goals and performance of system components; and system management still underpins such studies. In other studies in management, useful notions including hierarchy, inputs, outputs and transformation processes, chains of effect, relaxation time between action and effect, feedback both positive and negative, systems dynamics and cybernetic intervention, have stimulated specialist studies and even academic sub-disciplines (Pidd, 2004). In the ports literature recent studies have typically attempted to define performance using measures of finance, efficiency or effectiveness (Yeo *et al.*, 2008), or adopted a functionalist stance (Verhoeven, 2010). However, recent interest in the environmental management and performance of ports has often either been mainly scientifically based within academic communities or concerned with applications of methodologies available only to member based organisations. There is considerable scope for developing a systematic methodology which is accessible to practitioners and all ports alike. As briefly described below, some of the concepts of business systems engineering provide a useful basis on which to develop such a methodology.

To encourage ownership and commitment by port managers requires a process of environmental assessment which individual ports are able to undertake and own. To develop environmental awareness and local management of it, this process should be staged (Paipai, 1999). The systems approach commences by formulating strategy, progresses via the tactics required to establish processes and finally defines the tasks required to operate it. Because the environmental impacts of bunkering operations extend beyond the immediate control of port authorities, a holistic approach is essential. To meet these criteria and complement the procedures reported above, a systems approach was applied to assist observation, understanding and analysis of the issues involved. Business systems engineering aims to understand, document, simplify and optimise processes and more specifically, process mapping focuses on the stages of understanding and documenting. Lagoudis *et al.* (2004, 58) defined a system as a "group of interacting, interrelated, or interdependent elements, forming a complex whole" and Parnaby's (1979) input-output process modelling technique aims to identify functional units and flows that define processes in a company by defining the problem, system boundaries, function and variable flows. The technique proceeds by identifying processes at a strategic level, which affect present and future operations and their potential impacts. Next, it defines service processes which are tactical, in which service level and quality are guaranteed through the integrity of processes. At output level, operational processes are defined. The levels also interact.

In this context, the systems approach aims to identify the inputs needed by a port authority to assess the environmental impact of offshore marine bunkering operations in the maritime environment, analyse the service processes that take place in everyday operations and determine the final result or output of these processes. In an exploratory application (Dinwoodie *et al.* 2009) of the systems approach decisions were required at strategic, tactical and operational levels, representing system inputs, services and outputs (Table 4). At strategic level, decisions (S1-S7) incorporate overall determination of objectives. At tactical level (T1-T7) decisions required to achieve the overall objectives. The operational level (O1-O6) requires decisions which keep the system within constraint limits and in accord with objectives. This paper applies the same structure to offshore marine bunkering operations to trial a more generic model.

Table 4 Systems model overview

Strategic level		**Tactical level**		**Operational level**	
Input		*Service processes*		*Output*	
S1	Mission statement	T1	Local familiarization	O1	Internal monitoring, reporting, archiving
S2	Physical conditions	T2	Operational conventions	O2	External communication, dissemination
S3	Governance issues	T3	Networking	O3	Recommendations
S4	Stakeholders	T4	Consultation	O4	Mitigations
S5	Local data	T5	Reviewing, monitoring	O5	Sustainability
S6	Management system	T6	Hire expertise	O6	Awareness
S7	Resource assessment	T7	Reporting		

Direct comparison with existing tools is inappropriate because the systems approach focuses on processes needed for assessment at strategic, tactical and operational levels and some components may be revisited at different levels. Stakeholders for example are engaged as inputs (S4), processes (T1, T3, T4) and outputs (O6) and communication comprises processes (T1, T3, T4, T6), and outputs (O1, O2, O6). Indicative mapping of levels (Tables 5 to 7) arbitrarily against the SDM (Darbra *et al.*, 2004) and ISO14001 (ISO14000, 2009) reveals less emphasis on individual responsibilities or targets. This reflects the systems approach objective of assessing potential environmental impacts, rather than environmental management systems. The oblique mapping reveals proximate correspondence of categories (Table 5, S2) or actions (S6i) or null links (Table 7, O3ii).
In case based research, the case is the prime focus of interest and because many ports are unique, a case study research strategy allows the systems approach, as the phenomenon under study, to remain embedded within this unique context (Dinwoodie and Xu, 2008). However, if the systems approach is sufficiently robust to assist assessment by FHC in this environmentally sensitive area, then by implication it is likely to be transferable to less sensitive settings even though inputs such as “physical condition” may be less intense. The case context of Falmouth Harbour, home of the UK’s largest offshore terminal for marine oil and fuel, is an appropriate testing ground.

3.2 Falmouth: the case context

FHC manage a UK trust port which seeks to proactively develop a sustainable approach to port operations and development opportunities. Located within the Fal Estuary in Southwest England, the third largest international natural deepwater harbour attracts all sizes of vessel for safe anchoring and bunkering facilities. Falmouth Bay hosts dry dock facilities, cruise liners which bring tourists, shipbroker, agent and chandler services (Falmouth Port, 2003). Falmouth hosts a historic built environment, spectacular natural setting, rich water ecosystem and valuable habitat. Regional development plans emphasize environmental sustainability and regional distinctiveness through prioritizing waterfront and harbour regeneration (Cornwall County Council, 2005). The Bay and Estuary incorporate SSSIs, Areas of Outstanding Natural Beauty (AONB), Special Areas of Conservation (SAC) and Heritage Coasts and port authorities must ensure that marine operations do not harm these (Falmouth Port, 2009). Four harbour authorities operate within the boundaries of the Fal estuary where FHC have responsibility for areas where bunkering operations frequently take place. FHC manage the Inner Harbour excluding the docks, regulates the Harbour Area, and manages the Bay, Southern Carrick Roads, Eastern Penryn River and operates small craft facilities for the public (Falmouth Port, 2003; World Port Source, 2005 shows a map). All profits arising from commercial activities are reinvested in port development (Falmouth Port, 2007). Port management is open to public examination and responsible to interested stakeholders (DfT, 2000). Applicable safe standards are implemented through compliance with the Port Marine Safety Code (PMSC, Falmouth Port, 2009).

Juxtaposed with the world's busiest shipping lanes, bordering the post-August 2007 5 degree west SECA zone, and unrestricted by draught restrictions, Falmouth's offshore marine bunker station offers a continuous service in a protected harbour (Falmouth Port, 2003). As the marine oil terminal bunkering operator, Falmouth Oil Services Limited (FOS) has an EMS which takes into consideration bunkering operations. Via barges, road tanks or pipe, FOS offers all grades of fuels and lubricants to vessels and comprehensively delivers services including deliveries of gas oil and fresh water. As owner and operator of a 50kt shore-side bunker station FOS stores fuel for delivery to vessels anchored alongside or sheltering locally (Falmouth Port, 2003). FOS manages fuel deliveries, supported by a large independent bunker supplier and barge operator, which arranges bunker sales (FOS, 2009). The oil terminal contains three tank farms, clean oil and fuel oil loading racks, slop reception and processing facility (FOS, 2009). Local sales of Low Sulphur Fuel Oil spiralled post-2007 as ships comply with SECA zone emissions regulations (Falmouth Packet, 2007), serviced by two bunker barges. Current barge capacity is 2.4kt of fuel, 300t gas and lube oil and 50m^3 of slops for vessels requiring de-slopping during offshore bunkering. Maximum pumping rates are 400t/hr for fuel oil and 150t/hr for marine gas oil. Both can be undertaken simultaneously (Falmouth Port, 2003).

FOS' Quality Management System commits to standard personnel training and regular exercises to ensure that all personnel and equipment are fully prepared (FOS, 2009). Policies span quality, environment and oil pollution and each commits to continual improvement and strives to exceed mandatory requirements. Environmental policy commits to minimize adverse impacts and provide services to benefit the environment. Adverse effects include "potential contamination of land… pollution of controlled waters with petroleum products, production of waste residues… emissions to air… impacts associated with transportation [and] environmental nuisance, including odour emission and noise generation". FOS aims to manage the causes of impacts to minimise any effects, ensuring that "'significant harm' is not being caused to the environment, reduce all uncontrolled discharges of petroleum products to land and water, under normal operating conditions, to zero, and introduce all necessary controls to ensure… no accidental release of petroleum products to the environment". FOS will *inter alia* respond proactively to complaints and consider the environmental performance of key suppliers. Oil pollution policy seeks to prevent spills, protect watercourses, contain spread, recover and dispose of oil spill emulsion, clean up affected areas and report and cooperate in cleaning up larger spills. An Oil Pollution Control Manual detailing procedures, responses, actions, training and exercises is circulated to external organizations informing them of FOS' capabilities and restrictions. It reflects corporate operations, national legislation, local procedures, plans and the aim of environmental policy (FOS, 2009).

FHC environmental policy is to maintain and improve the port environment by working with environmental agencies in accordance with UK environmental legislation and international conventions. Staff education and training aims to conserve and enhance the local environmental quality (Falmouth Port, 2009) and an ECP guides human activities which could cause negative impacts. Harbour authorities provide waste reception facilities. An EMS details legislation and regulations notified by trade associations including BPA, EcoPorts, and government bodies. All internal or external communications are recorded including complaints and environmental correspondence pertaining to port operations and commercial activities, and consultants should be appointed to audit and review activities or conduct an EIA if impacts are significant. All targets and objectives focus on mitigation and applicable safe standards are required to comply with the PMSC (Falmouth Port, 2009).

4 RESULTS AND DISCUSSION

4.1 Strategic inputs

As a prime strategic input the FHC mission statement (S1, Table 5) commits to working closely with environmental agencies, protecting and conserving the environment and adhering to national environmental legislation and internationally agreed conventions. There is also an education and training dimension (Falmouth Port, 2009). Physical conditions (S2) list local designations. These eschew unsustainable developments (S2i, Cornwall-AONB, 2009), require avoidance of deterioration to habitats and disturbance to species (S2ii) and protect the coastline from undesirable development (S2iii). Establishing contacts with governance inputs oblige consultation and compliance locally (S3i). National government and statutory inputs (S3ii) engage the Environment Agency (UKEA) which seeks to protect and improve the environment, and via Water Framework Directives to prevent deterioration in, and to restore, water quality. Other inputs span the Department for Transport (DfT) and Department for Environment, Food and Rural Affairs (DEFRA), Maritime Management Organisation which administers planning, licensing activities, marine nature conservation, public access to coastal areas and fisheries management and 2009 Planning Act which guides decisions on major infrastructure development, including harbours. Because bunkering operations may potentially impact on air and water quality or pollution, they are heavily regulated. Supranational influences (S3iii) include Codes of Practice to facilitate sustainability (ESPO, 2003); IMO and other conventions underpinning transport, handling and storage of dangerous substances in ports (IMO 2009), Dumping at Sea and protection of the maritime environment from oil pollution arising from shipping operations (Paipai, 1999).

Table 5 Strategic level inputs

Strategic level				
Input		*Port authority lists:*	*ISO14001 section*	*SDM section*
S1	Mission statement	its environmental obligations	4.2	1A
S2	Physical conditions	physical designations e.g.	1C	4.3.2
i)		AONB		
ii)		SAC		
iii)		Heritage Coast		
S3	Governance issues	authorities it is answerable to	1C	4.3.2
i)		locally		
ii)		nationally		
iii)		supranationally		
S4	Stakeholders	groups interested in its operations	4B	4.4.3
i)		marine agencies		
ii)		environmental interest groups, voluntary and statutory	1C	4.3.2
iii)		suppliers		
S5	Local data	information available locally to		
i)		baseline port operations	1D	4.3.3
ii)		baseline resource monitoring	1D	4.3.3
S6	Management system	how activities will be monitored via		
i)		an EMS	7A	4.5.1
ii)		benchmarking	8A, 8B	4.5.4
iii)		professional bodies	8A, 8B	4.5.4
S7	Resource assessment	how it will acquire and manage funding of assessments	1E	4.4.1

Engagement with stakeholder inputs includes agencies such as Cornwall Sea Fisheries charged with maintaining a well managed, sustainable and regulated fishery and flexible patrol service (S4i). Voluntary environmental interest groups (S4ii) include Friends of the Earth which aims to protect the rights of all people to live in a safe and healthy environment; statutory groups include the Marine Conservation Society which promotes clean seas and beaches, sustainable fisheries, and marine life. Suppliers and sub-contractors in building and maintenance works are screened (S4iii). Local data inputs of objectives and targets for a port EMS require mapping and monitoring of local management systems. Baseline operations are reviewed (S5i) alongside resource monitoring of databanks, information retrieval, surveys, recording systems, and modelling software to predict oil spill movements (s5ii). Management systems require an EMS (S6i) to stow relevant legislation and data to drive continuous improvements in environmental quality and prevent pollution. Guidance is available (Saengsupavanich *et al.*, 2009; ESPO, 2003). Local authorities (S6ii) detail EIAs required or environmental issues embedded in local policies, plans and programmes which must be complied with (Paipai, 1999). Membership (S6iii) of EcoPorts and BPA who collaborate and contribute to establish best practice can guide an EMS. Finally, resource assessment (S7) underpins the FHC mission of commercial viability, which requires the costing and funding of all activities. Financial resources accrue from harbour charges and other services provided or government funding such as Knowledge Transfer Partnerships with universities.

4.2 Tactical level

Table 6 Service levels processes

Service processes		***Port authority plans***	***ISO14001 section***	***SDM section***
T1	Local familiarisation	How to provide relevant information using		
i)		harbour tours	4B	4.4.3
ii)		researching client organizations	4A	4.4.3
iii)		establishing stakeholder groups	4B	4.4.3
iv)		local monitoring technologies	7B	4.5.1
T2	Operational conventions	What to comply with and how in local operations	1C	4.3.2
T3	Networking	Who to contact and how through	4B	4.4.3
i)		site visits to other ports		
ii)		developing relations with environmental agencies		
iii)		stakeholder analysis		
T4	Consultation	Who to consult and when including	4B	4.4.3
i)		experts		
ii)		professional bodies/ trade associations		
iii)		stakeholders		
T5	Reviewing and monitoring	What data to gather, how, and how to analyse and store it including		
i)		incident records	7A,6	4.5.3,4.4.7
ii)		sampling operations	7B	4.5.2
iii)		monitoring incidence and impact	8B	4.6
iv)		EMS and consumer satisfaction reporting	7B	4.5.1
T6	Hire expertise	Who to hire in and when including		
i)		environmental consultants	2A,2B	4.4.1
ii)		public relations companies	4B	4.4.3
iii)		staff training	3	4.4.2
iv)		client education and training	4B	4.4.3
T7	Reporting	How to store data on incidents/ operations	5D	4.4.5

Table 6 describes tactical level service processes. To facilitate local familiarisation FHC arrange tours of relevant facilities (T1i) and research client organizations (T1ii). Establishing an internal stakeholder group (T1iii) embraces harbour authorities, bunker operator and pilotage and other services. Action T1iv requires systems to record all bunkering operations and data to enable FHC to identify any changes, and the frequency of any environmental impacts. Buoys are acquired and set up to gather data to update tidal modelling and inform PISCES oil spill prediction software.

FHC requires procedures to guide those involved with supplying bunkers to ensure that operations minimise the risks of environmental damage (T2). MARPOL conventions seek to prevent pollution caused through carrying or delivering oil products, vessel wastes and emissions, and control pollution involving noxious bulk liquids. SOLAS (Safety of Life at Sea) conventions apply to ships involved in receiving and supplying fuel at sea relating *inter alia* to fire protection, safety navigation, carriage of dangerous goods, and safety management (IMO, 2009b). As a polluting bulk liquid, transfers of marine diesel must comply with relevant codes (IMO, 2009c) and the design and construction of ships carrying liquefied gases is regulated (IMO, 2009d). EU Directive 2002/59/EC sets minimum standards for the safe transport of dangerous and polluting goods by sea, and port operations in Europe (ESPO, 2003). UK Merchant Shipping (Ship-to-Ship Transfer) Regulations 2008 govern transfers between ships, of cargo or bunker fuel involving hazardous substances in UK waters (MCA, 2008). Operating guidelines cover bunkering equipment, communication system, fire fighting, and pollution prevention equipment. Safety concerns include vessel condition, responsible personnel, quantity demanded and emergency plans (UK P&I Club, 2008b).

Tactical actions to establish networking instigate site visits and shared experiences with ports (T3i) that demonstrate best practice. To build relations with environmental groups and agencies (T3ii) requires regular meetings, email and telephone contact and stakeholder analysis (T3iii) to facilitate consultation (Falmouth Port, 2009). Actions to establish consultation engage experts from universities and Natural England (T4i) and initiate consultations (T4ii) with BPA to access advice on legislative and policy issues, exchange knowledge and develop best practice. When established, contacts in UKEA, DEFRA and other agencies email notifications or advertise meetings as environmental obligations arise. Action T4iii requires updated contacts lists, stakeholder analysis, identification of contacts and communication to identify their concerns.

Service processes to enable review and monitoring of the environmental impacts and assess scope for simplifying operations require a database detailing procedures, frequencies and their impacts (T5i). To assist national and local emergency authorities to enact oil spill contingency plans (ESPO, 2003) FHC undertakes proactive local oceanographic modelling of pollution incidents using GIS databases of hydrographic and tidal records. To update them requires tactical decisions on how and where to sample (T5ii). IMO's convention on Oil Pollution Preparedness, Response and Cooperation requires measures for dealing with oil pollution incidents. FHC cooperates with national and local authorities in preparing contingency plans, promoting awareness of existing contingency plans, communicating this knowledge internally and assisting coordination of contingency plans (ESPO, 2003). The UK Maritime Coastguard Agency maintains a national contingency plan for marine pollution from shipping and offshore installations (DfT, 2000). European Directive 2002/59 proposed that the UK conducts Port State Control inspections to ensure that the condition and equipment of foreign ships complies with international conventions and that their operation is consistent with international law. Port authorities contribute to improve the safety of navigation and prevent pollution (ESPO, 2003) and the UKPMSC requires all ports to carry out risk assessment for marine operations to implement the SMS for managing navigation. Under the PMSC risks must be identified and evaluated and suitable controls established to manage them, with clear linkages between risk controls, operating procedures, harbour by-laws and safety management (Risk Support, 2001). This standard offers a framework for preparing policies and plans (Paipai, 1999; Falmouth Port, 2009). Complex regulation requires actions to establish monitoring systems (T5iii) and report key indicators, consumer satisfaction and the impacts of mitigations and monitoring (T5iv).

Processes facilitate actions T6i and T6ii, perhaps to publicise particular activities or manage media engagement surrounding oil spills or pollution incidents. Tactical provision of environmental awareness training (T6iii) may encourage membership of trade associations including the BPA to facilitate conference attendance and port visits to share best practice. The FHC mission to provide "education and training…to ensure that everyone using our waterways does so with a respect for their impact on the environment" (Falmouth Port 2009), points towards processes to engage specialist training providers for users of bunkering facilities (T6iv). Procedures are required (T7) to archive records of bunkering operations which log changing port activities (Paipai, 1999). Records are available to authorities and stakeholders and inform the EMS and are updated as legislation changes.

4.3 Operational level

Through well coordinated output processes (Table 7) FHC increasingly monitors how far consumers are satisfied with how it manages environmental assessments. Operational actions include monitoring programmes (O1i) to identify whether port users perform bunkering operations to standard. Environmental performance indicators are being defined to facilitate continuous updating and eventually, publication of an annual environmental report (ESPO, 2003). Action O1ii will document relevant issues and communications with environmental stakeholders. If shared electronically, it will assist staff to access information, raise awareness of legislation and obligations, and ensure compliance. Action O1iii will require a comprehensive baseline database which includes reports, documents and operator records.

Indicative action O2i raises FHC's professional profile and awareness of best practice and O2ii provides information sharing online before activities are assessed in compliance with Directive 2003/04EC, which requires port administrations to process and update environmental information pertaining to their activities and projects. Media contact (O2iii) broadcasts FHC's environmental credentials (ESPO, 2003) and updates for stakeholders (O2iv) enhance local engagement with for example local AONB Partners and visitors who pick up leaflets.

Updates to FHC's ECP (O3i) for public and commercial harbour users seek to ensure compliance with Water Framework, SAC and EU Habitat Directives. This action entices bunker operators to apply ISGOTT (ICS, 2006) and procedures should be incorporated in the ship's SMS to ensure that risks have been assessed and mitigation controls established. Oil spill contingency arrangements are required. Action O3ii requires networking with agencies such as DEFRA.

Action O4 requires FHC to explain how its evidence base is collated and monitoring procedures are established. Systems record (O4i) and assess (O4ii) FHC performance. To retain clients and enhance customer relations, the system incorporates procedures to handle complaints, litigation, appeals against decisions and compensation issues.

Table 7 Output processes

	Output	Port authority will	ISO14001 section	SDM section
O1	Internal monitoring, reporting, archiving	Collect, record, present and store key data. Set up:		
i)		monitoring scheme	7A	4.5.1
ii)		environmental library	4A	4.4.3
iii)		CSR reporting	4B	4.4.3
O2	External dissemination and communication	Share information with third parties via	4B	4.4.3
i)		trade associations and conferences		
ii)		stakeholder communications strategy		
iii)		press reporting		
iv)		newsletters		
O3	Recommendations	Inform and update users and authorities through		
i)		updated environmental codes of conduct	5B	4.4.6
ii)		inputs to policy making		
O4	Mitigations	Set up management procedures, manuals and systems to respond to issues of user compliance by		
i)		registering and recording complaints	5B	4.4.6
ii)		consumer satisfaction surveys	8B	4.6
O5	Sustainability	Promote and monitor sustainable operations	5A	4.3.4
O6	Awareness	Establish and promote best practice by		
i)		educating stakeholders	4B	4.4.3
ii)		establishing awareness and training materials	3	4.4.2

To promote the ethos and practice of sustainability (O5), FHC conducts regular spot checks on operations to ensure compliance with relevant Codes. FHC underscores its own corporate environmental awareness (O6i) by aspiring to share knowledge of legislation and best practice with schools and community groups, perhaps via leaflets for marina users or instructions for ships requesting piloting services online. Given that human error causes most accidents, actions (O6ii) aim to share knowledge of legislation, good practice and mitigation procedures and ensure that personnel are qualified to conduct safe operations and prepared to tackle spillages. Training is time and cost-efficient in raising awareness, developing in-house capability and enhancing individual skill competences to ensure that policy objectives are implemented (ESPO, 2003).

5 CONCLUSIONS

Application of the systems approach assists FHC to remain compliant with complex codes and regulations, and to pro-actively develop an evidence based approach to enhance the sustainability of routine offshore marine bunkering operations and developments in its bailiwick. By proactively encouraging professional engagement and collaboration with complementary initiatives from bodies including BPA, EcoPorts and ISO which engage extensively in benchmarking and sharing best practices, the systems approach complements the drive for continuous improvement. Further, because the systems approach is parsimonious (Table 8) direct implementation by port authorities rather than relying on external evaluation by EcoPorts or ISO, heightens local ownership of the evaluation process and embedding of environmental awareness into FHC.

Table 8 Summary of the systems model

Strategic level		**Tactical level**		**Operational level**	
Input		*Service processes*		*Output*	
S1	Mission statement	T1	Local information	O1	Internal reporting
		i	harbour tour	i	monitoring scheme
		ii	research client	ii	environmental library
		iii	stakeholder group	iii	CSR reporting
		iv	local technology		
S2	Physical conditions	T2	Operational	O2	External information
i	AONB		conventions	i	trade body/conferences
ii	SAC			ii	stakeholder strategy
iii	Heritage coast			iii	press reporting
				iv	newsletters
S3	Governance issues	T3	Networking via	O3	Recommendations on
i	local	i	port visits	i	codes of conduct
ii	national	ii	agencies	ii	policy making
iii	supranational	iii	stakeholders		
S4	Stakeholders	T4	Consult	O4	Mitigations
i	agencies	i	experts	i	register complaints
ii	interest groups	ii	professional body	ii	consumer surveys
iii	suppliers	iii	stakeholders		
S5	Local data:	T5	Review, monitor	O5	Promote sustainability
i	baseline operations	i	incidents		
ii	baseline resources	ii	operations		
		iii	impacts		
		iv	EMS, consumers		
S6	Management	T6	Hire expertise	O6	Awareness
	system	i	consultants	i	educate stakeholders
i	EMS	ii	public relations	ii	training materials
ii	benchmarks	iii	staff training		
iii	professional body	iv	client education		
S7	Assess resources	T7	Reporting		

One spin-off of local engagement is increased stakeholder engagement which has stimulated numerous new contacts and offers of reciprocal information sharing. Environmental interest groups voluntarily contribute new monitoring capability. Proactive searches for additional funding attracted a Knowledge Transfer Partnership which funds a sustainable developments officer who relieves the Harbour Master from attending routine meetings and enhances the port authority's professional profile and capability to engage in technical developments, debate, and policy making.

Explicit focus on developing new local data gathering, analysis and forecasting technologies including powerful PISCES oil spill modelling software, has significantly increased the capability of FHC to record, predict and mitigate the likely impacts of untoward events. Using the systems approach, explicit outputs relating to awareness, will enhance the link with employee and user training and community and stakeholder involvement, further reducing the risk of mishaps. Continuously enhanced outputs of data collection, monitoring, recording and consumer feedback raise FHC awareness of and capability to achieve its mission.

Should other port authorities adopt the systems approach? Because few authorities manage physical strategic inputs as sensitive as at Falmouth, most will require fewer local data inputs. Many would benefit from tactical management of service processes, through networking and consultation which raises awareness of operational conventions and reduces costs of hiring in expertise. Local ownership of, and commitment to, the evaluation process is enhanced. Future testing of the taxonomy of inputs and outputs presented may reveal the influence of port ownership and governance structures, or varying operational benefits arising from adopting the systems approach. Authorities which currently rely on methodologies and tools driven by primarily physically based environmental monitoring and auditing systems may benefit from complementary application of this mission driven input-output process modelling technique which highlights the importance of stakeholder engagement and building social capital and awareness.

ACKNOWLEDGEMENTS

Plymouth Business School teamed up with Falmouth Harbour Commissioners in a Knowledge Transfer Partnership (No. KTP007098). This Partnership received financial support from the Knowledge Transfer Partnerships programme. KTP aims to help businesses to improve their competitiveness and productivity through the better use of knowledge, technology and skills that reside within the UK Knowledge Base. KTP is funded by the Technology Strategy Board along with the other government funding organizations which included the National Environment Research Council, the Economic and Social Research Council and FHC. None of these bodies was involved in decisions relating to research design, data collection, data analysis, interpretation or dissemination.

REFERENCES

Alizadeh, A.H and N.K. Nomikos (2004). The Efficiency of the Forward Bunker Market. International Journal of Logistics: Research and Applications, 7, 3, 281-296.

ASTM (1993). Chapter 600: Marine Oil Terminal Rules. Oil Discharge Prevention and Pollution Control Rules for Marine Oil Terminals, Transportation Pipelines and Vessels. American Society for Testing and Materials, Department of Environmental Protection 06-096. Available from: http://www.bing.com/search?q=ASTM+bunkering+protocol+1993&FORM=MSNH90&mkt=en-gb (Accessed 20th October 2009).

BPA (2009). Our Goals. [Online] British Port Association. London. Available from: http://www.britishports.org.uk/public/about_us/our_goal (Accessed 4th August 2009).

Cetin, C.K. and A.G. Cerit (2010). Organisational effectiveness at seaports: a systems approach. Maritime Policy and Management, 37, 3, 195-219.

Chang, Y.C. and C.C. Chen (2006). Knowledge-based simulation of bunkering services in the port of Kaohsiung. Civil Engineering and Environmental Systems, 23, 1, 21–34.

Churchman C. W., (1979). The Systems Approach, 2nd ed. Laurel, New York.

Cornwall County Council (2005). Cornwall and Scilly Urban Survey: historic characterization. Historic Environment Service, Truro, UK.

Cornwall-aonb (2009). The Cornwall AONB Partnership [online] Cornwall AONB, Truro, UK. Available from: http://www.cornwall-aonb.gov.uk/partnership.html (Accessed 1st August 2009).

Darbra, R., N. Pittam, K. Royston, J. Darbra and H. Journee (2009). Survey on environmental monitoring requirements of European ports. Journal of Environmental Management, 90, 3, 1396-1403.

Darbra, R., A. Ronza, T. Stojanovic, C. Wooldridge and J. Casal (2005). A procedure for identifying significant environmental aspects in sea ports. Marine Pollution Bulletin, 50, 8, 866-874.

Darbra, R., A. Ronza, J. Casal, T. Stojanovic and C. Wooldridge (2004). The Self Diagnosis Method. A new methodology to assess environmental management in sea ports. Marine Pollution Bulletin, 48, 420-428.

DfT (2000). Modern ports: A UK policy. [Online] Department for Transport, London. Available from: http://www.dft.gov.uk/pgr/shippingports/ports/modern/modernportsaukpolicy?page=1 (Accessed 23rd May 2009).

DfT (2002). A project appraisal framework for ports. [Online] Department for Transport, London. Available from: http://www.dft.gov.uk/consultations/archive/2002/afp/ (Accessed 23rd May 2009)

DfT (2006). Focus on Ports, 2006 edition. Department for Transport, London.

Dinwoodie, J., H. Knowles, S. Tuck and J. Benhin (2009). Assessing the environmental impact of maritime operations in smaller ports: a systems approach. In: Logistics Research Network 2009 Conference Proceedings, Cardiff, September, pp. 536-543. Chartered Institute of Logistics and Transport, Corby, UK.

Dinwoodie, J. and J. Xu (2008). Case studies in logistics: a review and tentative taxonomy. International Journal of Logistics Research and Applications, 11, 5, 393-408.

EcoPorts (2006). The Top-10 Port Environmental issues. [Online] EcoPorts, Brussels. Available from: http://www.ecoports.com/page.ocl?pageid=127 (Accessed on 21st June 2009).

ESPO (2003). ESPO Environmental Code of Practice. [Online] European Sea Ports Organisation, Brussels. Available from: http://www.espo.be/downloads/archive/85817e87-5a24-4c43-b570-146cb7f36b68.pdf (Accessed on 2nd August 2009).

Falmouth Packet (2007). 'Falmouth for oil' demands see port working around the clock. [Online] Falmouth Packet, Falmouth, UK. Available from: http://www.falmouthpacket.co.uk/news/fpboating/1618388.___Falmouth_for_oil____demands_see_port_working_around_the_clock/ (Accessed on 1st June 2009).

Falmouth Port (2003). The Falmouth and Truro Ports Handbook. [Online] Falmouth Port, Falmouth UK. Available from: http://www.falmouthport.co.uk/pdf/ports_handbook.pdf (Accessed on 20th May 2009).

Falmouth Port (2007). Falmouth Habour Commissioners' Strategy. [Online] Falmouth Port, Falmouth, UK. Available from: http://www.falmouthport.co.uk/pdf/strategy2007.pdf (Accessed on 20th May 2009).

Falmouth Port (2009). Falmouth Harbour Commissioners Environmental Policy. [Online] Falmouth Port, Falmouth, UK. Available from: http://www.falmouthport.co.uk/pdf/FHC-environmental-policy.pdf (Accessed on 20th May 2009).

Fisher, C. and J. Lux (2004). Bunkers - An Analysis of the Practical, Technical and Legal Issues**.** English 3rd ed., Lloyds List Publications, London.

FOS (2009). Falmouth Oil Services Limited. [Online] Falmouth, UK. Available from: http://www.fosoil.com/ (Accessed on 20 October 2009).

Gilman, S. (2003). Sustainability and national policy in UK port development. Maritime Policy and Management, 30, 4, 275-291.

Hannon, P.D. and A. Atherton (1998). Small firm success and the art of orienteering: the value of plans, planning and strategic awareness in the competitive small firm. Journal of Small Business and Enterprise Development, 5, 2,102-119.

Helcom (2009). Helcom Recommendation 24/6. Guidelines on Bunkering Operations and Ship To Ship Cargo Transfer of Oils, Subject to Annex I of Marpol 73/78, In The Baltic Sea Area Helsinki Commission. [Online] Baltic Marine Environment Protection Commission, Helsinki. Available from http://www.helcom.fi/Recommendations/en_GB/rec24_6/ (Accessed on 20 October 2009).

ICS (2006). ISGOTT: International Safety Guide for Oil Tankers and Terminals. 5th ed. International Chamber of Shipping, London; Oil Companies International Marine Forum, Bermuda; International Association of Ports and Harbors.

IMO (2002). International Safety Management (ISM) Code. [Online] International Maritime Organisation, London. Available from: http://www.imo.org/HumanElement/mainframe.asp?topic_id=287 (Accessed on 5th July 2009).

IMO (2009a). Review of the regulations to prevent air pollution from ships. [Online] International Maritime Organisation, London. Available from: http://www.imo.org/ (Accessed on 20th October 2009).

IMO (2009b). International Convention for the Safety of Life at Sea (SOLAS), 1974. [Online]. International Maritime Organisation, London. Available from:

http://www.imo.org/Conventions/contents.asp?topic_id=257&doc_id=647 (Accessed on 20th October 2009).

IMO (2009c). International Maritime Dangerous Goods (IMDG) Code. [Online] International Maritime Organisation, London. Available from: http://www.imo.org/Safety/mainframe.asp?topic_id=158(Accessed on 20th October 2009).

IMO (2009d). International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). [Online] International Maritime Organisation, London. Available from: http://www.imo.org/environment/mainframe.asp?topic_id=995 (Accessed on 20th October 2009).

ISO (2009). ISO/FDIS 13739, Petroleum products: Procedures for transfer of bunkers to vessels. [Online] International Organisation for Standardisation, Geneva. Available from: http://www.iso.org/iso/catalogue_detail.htm?csnumber=43387 (Accessed on 20th October 2009).

ISO14000 (2009). ISO14000 ISO14001 Environmental Management. (Online) ISO14000 Environmental Management Group, Bootle, UK. Available from: http://www.iso14000-iso14001-environmental-management.com/ (Accessed on 12 June 2009).

Kast, F.E. and J.E. Rosenzweig (1972). General systems theory: Applications for organisation and management. The Academy of Management Journal, 15, 4, 447-465.

Lagoudis, I.N., C.S. Lalwani and M.M. Naim (2004). A generic systems model for ocean bulk shipping companies in the bulk sector. Transportation Journal, Winter, 56-76.

Lloyds Register (2005). Practical guidelines for handling MARPOL 73/78, Annex VI Regulations 14 and 18. (Online) Lloyds Register FOBAS, London. Available from: http://www.lr.org/Publications/FOBAS+Annex+VI.htm (Accessed on 20th October 2009).

MCA (2008). Guidance on the Merchant Shipping (Ship-to-Ship Transfer) Regulations 2008. [Online] Maritime and Coastguard Agency: London. Available from: http://www.mcga.gov.uk/c4mca/080511_mgn_for_cons.pdf (Accessed on 5th August 2009).

Notteboom, T. and J. Rodrigue (2005). Port regionalisation: Towards a new phase in development. Maritime Policy and Management, 32,3, 297-313.

Oxford Economics (2009). The Economic Contribution of Ports to the UK Economy. Abbey House, Oxford.

Paipai, E. (1999). Guidelines for Port Environmental Management. Report SR 554. HR Wallingford, Department of the Environment, Transport and the Regions, London.

Parnaby, J. (1979). Concept of Manufacturing System. International Journal of Production Research, 17, 2, 23-135.

Peris-Mora, E., J.M. Diez Orejas, A. Subirats, S. Ibanez and P. Alvarez (2005). Development of a system of indicators for sustainable port management. Marine Pollution Bulletin, 50, 1649-1660.

Pettit, S. (2008). United Kingdom ports policy: Changing government attitudes. Marine Policy, 32, 4, 719-727.

Pidd, M. (2004). Systems Modelling: Theory and Practice, 2nd ed. Wiley, London.

Risk Support (2001). Linking Risk Assessment of Marine Operations to Safety Management in Ports. [Online] Risk Support Limited. London. Available from: http://www.risk-support.co.uk/vmt_MTS2001.pdf (Accessed on 3rd June 2009).

Robinmeech (2009). Outlook for Marine Bunkers and Fuel Oil to 2025 Sourcing Lower Sulphur Products. [Online] Robin Meech, Oxford. Available from: http://www.robinmeech.com/Bunker%20and%20Fuel%20Oil%20Study%20JAN%202009%20.doc (Accessed on 17th June 2009).

Saengsupavanich, C., N. Coowanitwong, W. Gallardo and C. Lertsuchatavanich (2009). Environmental performance evaluation of an industrial port and estate: ISO14001, port state control-derived indicators. Journal of Cleaner Production, 17, 2,154-161.

SSA (2009). SS 600: 2008. Code of practice for bunkering. [Online] Singapore Shipping Association, Singapore. Available from: http://www.ssa.org.sg/index.cfm?GPID=76 (Accessed 17th June 2009).

Steamship Mutual (2008). Oil Spills During Routine Bunkering Operations. [Online] Steamship Mutual, London. Available from: http://www.simsl.com/BunkerSpills0508.html (Accessed 17th June 2009).

Talley, W.K., D. Jin and H. Kite-Powell (2001). Vessel accident oil-spillage: post US OPA-90. Transportation Research Part D, 6, 405-415.

Talley, W.K. (1999). Determinants of the property damage costs of tanker accidents. Transportation Research Part D, 4, 413-426.

UNESCAP (2009). Environmental impacts of port development. [Online] United Nations Economic and Social Commission for Asia and the Pacific, Bangkok. Available from: http://www.unescap.org/ttdw/Publications/TFS_pubs/Pub_1234/pub_1234_ch2.pdf (Accessed on 19th June 2009).

UK P&I Club (2008a). Sulphur content of gas oil – UK. [Online] UK P&I Club, London. Available from: http://www.ukpandi.com/ukpandi/infopool.nsf/html/LPBulletin562 (Accessed 20th July 2009).

UK P&I Club (2008b). Preventing pollution during bunkering operations. [Online] UK P&I Club, London. Available from: http://www.ukpandi.com/ukpandi/InfoPool.nsf/HTML/LPNewsHead20081107 (Accessed 15th July 2009).

Van der Veen, M. (2006). The Port Environmental Review System and the Self Diagnosis Method, SDM. International Conference on Coastal and Ocean Governance, One Ocean, One People, One Vision, Haikou City, China, December.

Verhoeven, P. (2010). A review of port authority functions: towards a renaissance. Maritime Policy and Management, 37, 3, 247-270.

Videotel (2009). STCW Controlling the Operation of the Ship and Care for Persons on Board. [Online] Videotel, London. Available from: http://www.videotel.co.uk/catalogue/s03_09.asp (Accessed on 15th May 2009).

Wang, C. and J.J. Corbett (2007). The costs and benefits of reducing SO2 emissions from ships in the US West Coastal waters. Transportation Research Part D,12, 577-588.

Wooldridge, C., C. McMullen and V. Howe (1999). Environmental management of ports and harbours: implementation of policy through scientific monitoring. Journal of Marine Policy, 23, 4-5, 413-425.

World Port Source (2005). Port of Falmouth. [Online] World Port Source, San Jose. Available from: http://www.worldportsource.com/ports/map.2866.1529.php (Accessed on 20th June 2009).

Yeo, G-T., M. Roe, J. Dinwoodie, (2008). Evaluating the Competitiveness of Container Ports in Korea and China. Transportation Research A, 48, 6, 910-921.