Knowledge capture to inform sustainable maritime operations

Journal:	*International Journal of Operations and Production Management*
Manuscript ID	IJOPM-10-2015-0657.R4
Manuscript Type:	Research Paper
Keywords:	Ethnographic Content Analysis, Sustainable Operations, Maritime Operations, Knowledge management

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Purpose - The purpose of this paper is to report an explicit taxonomy of maritime operations (MO) to guide Harbour Masters (HM)s of smaller ports in planning more sustainable operations.

Design/methodology/approach – This research presents strategies for building theory to promote more sustainable port management in a two-stage research design. Starting from a base taxonomy in research stage one, ethnographic content analysis (ECA) of a sparse prior literature on MO generated a tentative taxonomy. In stage two, interviews to capture tacit practitioner knowledge refined the tentative taxonomy into a credible practitioner-informed final taxonomy.

Findings - ECA offers researchers a powerful tool to analyse complex operational problems. In this paper MOs are represented in an explicit taxonomy.

Practical implications – A final taxonomy of MOs guides sustainability strategy formulation by HMs and assists them to protect vital commercial revenues which serve supply chains and local communities.

Originality / value - An explicit final taxonomy of MO is derived using a novel methodology. The taxonomy guides sustainability strategy formulation and underpins subsequent planning of sustainable development policies.

Keywords Sustainable Operations; Ethnographic Content Analysis; Maritime Operations; Knowledge Management;

Paper type Research paper

1. Introduction

This research aims to devise an explicit taxonomy of maritime operations (MO) to guide Harbour Masters (HMs) in smaller ports in planning more sustainable operations in Cornwall and Devon (CAD), UK. According to United Nations (1987) requirements sustainable development must “meet the needs of the present generation without compromising the ability of future generations to meet their own needs”. In successful applications, a triple bottom line of sustainability engages environmental, societal and economic dimensions (Tullbeg, 2012). In the maritime sector, Harbour Commissioners’ mission statements typically incorporate all three dimensions (Kuznetsov et al., 2015). Scant published implications for devising practical strategies to manage MOs sustainably in local ports signify minimal research links with sustainability theory and deprive HMs of relevant prior explicit knowledge to inform a practical port sustainability management system (PSMS). Environmental issues abound in maritime strategies and policies (OECD, 2008; Ecoports, 2014) but environmental management obligations baffle many HMs who outsource such work to consultants where resources permit. Safety management underpins seafarer training and as ex-seafarers HMs understand such responsibilities. Diverse and complex port governance structures cloud obligations to operate commercially. Consequently, research is urgently required to assist HMs to formulate strategies to manage MOs sustainably.

HMs aim to safeguard vital revenue streams derived from commercial MO but ports which host unsustainable MOs risk exclusion from supply chains and economic ruin in local communities and regions (Kuznetsov *et al.*, 2015; Mangan *et al.*, 2008). Port survival depends on safeguarding diverse MOs which span fishing, small scale cargo, leisure related services, commercial bunkering and transhipment of regional cargoes (SWRPA, 2015). In turn, safeguarding of MOs requires sustainable management but HMs are powerless to formulate appropriate strategies until they understand local MO. Research is essential firstly to define MO, and secondly to devise sustainability management strategies by capturing the published knowledge available and knowledge embedded in HMs’ experience. In related fields such as supply chain management, early research into sustainability management focused on defining key concepts (Seuring and Muller, 2008). Later, research highlighted supply chain governance and performance issues (Gosling *et al.*, 2016). Perhaps maritime sustainability management research will exhibit similar trends.

This paper contributes a final taxonomy of MO, and novel research strategies to collect and analyse qualitative data to develop a PSMS (Kuznetsov *et al.*, 2015). Under Pilotage Acts (The Stationary Office, 1987), competent and compliant Harbour Authorities must oversee MO because proven non-compliance or incompetence implies that operations cease with revenue-losses. Tacit knowledge gathering must engage HMs or directly delegated officials who understand the practical responsibilities of duty-holder status in compliant and competent Harbour Authorities to be industrially credible, because MO are unsustainable if undertaken non-compliantly or incompetently. Processes to raise operational efficiency beyond safeguarding also require clear delineations of liabilities, clear responsibilities and transparent reporting.

The paper contributes a practical guide of methods to identify and analyse explicit knowledge where existing literature is scant, by establishing a theoretical background to underpin primary data collection to guide more sustainable MO. Commencing from a base taxonomy in stage one, secondary data is analysed to capture explicit knowledge to create a tentative taxonomy of commercial revenues derived from MO which underpin port logistics, supply chains and value chains. In stage two capture of tacit knowledge available primarily to HMs and testing of emerging theory refined the tentative taxonomy into a final taxonomy to underpin PSMS design to facilitate new business development.

In Section 2 literature is introduced relating to sustainable port management, knowledge management (KM) and creation, and the industrial significance of capturing tacit knowledge. Section 3 discusses methodological issues including Ethnographic Content Analysis (ECA) in research stage one and testing of the tentative definition of MO in stage two. Section 4 reports Pattern Analysis, and redefinition of MO following tacit knowledge collection. Section 5 considers implications of the findings for industrial and theoretical development and suggests directions for future study.

2. Literature review

2.1 The problem context: sustainable port management

Management challenges in smaller organisations include limited formal training, minimal long-term planning, and limited human and financial resources (Snider *et al.*, 2009). In small CAD ports, arbitrary sustainability planning may trigger oversights which jeopardise organisational survival, or inadvertently reveal unplanned sustainable competitive advantages. Within supply chains, ports assume operational roles that range from small transhipment centres to key logistics nodes (Mangan *et al.*, 2008). However, smaller organisations such as 700 smaller UK ports (Kuznetsov *et al.*, 2015) possess insufficient resources or technical expertise to assess the sustainability of their MO. South West Regional Ports Association (SWRPA) is an inter-organisational forum principally of HMs. Ongoing engagement presents a credible context within which to develop a methodology for taxonomy building to guide a PSMS.

In March 2012, scoping interviews with practitioners were initiated to identify key perspectives of MO and PSMS until after nine interviews, no new data emerged. Interviewees included HMs of one municipal and one trust port, a deputy HM, assistant HMs specialised in conservancy and operations, and managers of port environmental, financial and leisure services. The issues identified included current MO, the need for PSMS, and the form it might take. Interviews revealed that research should target only HMs and a few specialist officers because prime responsibilities for sustainability planning lie with HMs as Chief Executive Officers of Port Authorities. Scoping work and subsequent industry engagement confirmed that explicit knowledge is rarely recorded, few mechanisms are available to capture tacit knowledge (Morris *et al.,* 2006) and invaluable organisational resources to facilitate sustainable processes and sustainable operations management remain concealed (Blome *et al.,* 2014). The costs of hiring external expertise or non-compliance inhibit PSMS development (OECD, 2009).

Experience from other industries may assist PSMS design. Firstly, innovation for organisational sustainability can facilitate the creation of new business practices (Longoni and Cagliano, 2015) although faltering innovations in small enterprises reflect a struggle to compete effectively, and limited resources. Secondly, supply chain performance reflects the power of knowledge which is accessible to smaller firms through either a bespoke solution including a methodological step-by-step guide and a proven outcome, or costly investment. Thirdly, effective KM systems are often developed in-house because tacit knowledge is highly ambiguous (Schoenherr *et al.*, 2014) and investment may bankrupt smaller organisations (Snider *et al.,* 2009). Typically, literature searches generate insights which guide a novel approach or adjustments to existing systems which produce a bespoke KM system. Within the current context PSMS must offer an effective KM system.

2.2 Managing and creating knowledge within organisations

Scoping studies in CAD ports identified that increasing data availability has intensified requirements for systematic procedures to assist knowledge capture and KM (Kuznetsov, 2014). Terminology has been misused, creating confusion (Pearlson and Saunders, 2010) but sustainable competitive advantage requires clear definitions before focusing on the specific content and process of KM (Nonaka *et al.*, 2001). "Data" pertains to "simple observations of states of the world"; it is simple to capture, store, transfer, compact and quantify (Davenport, 1997, p.9). Information is "data endowed with relevance and purpose" (Drucker, 1999, p.124). Understanding of the meaning of information may involve mediation before consensus is achieved, and information may become garbled during transmission. Knowledge spans "contextual information, experiences, rules and values" involving "meaningfully organised accurate information through experiences, communication or inference" (Pearlson and Saunders, 2010, p.349). Knowledge requires storage, manipulation and a "process" of acting upon it, perhaps by applying expertise (Zack, 1999, p.46). Tacit knowledge is highly personal, difficult to capture electronically, difficult to structure and difficult to transfer (Pearlson and Saunders, 2010). Explicit knowledge is codified, easily communicated and transferred (Polanyi, 1966) and typically presented in "manuals, blueprints, procedures, policies, forecasts, inventory levels, production schedules, market intelligence data…" (Schoenherr *et al.,* 2014, p.123). It is "precisely and formally articulated, although removed from the original context" (Zack, 1999, p.46). In contrast tacit knowledge is "implicit, hard-to-conceptualise and subjective…part of an individual's experiences; …evidenced in behaviour or actions… often highly ambiguous…" (Schoenherr *et al.*, 2014, p.124). It is developed "from direct experiences and actions" and usually shared through interactions (Zack, 1999, p.46), based on viewpoints, beliefs and perspectives that individuals use to make sense of information in difficult situations in which new meanings can be created. PSMS design requires framework(s) to conceptualise the modes whereby knowledge regarding sustainable MO may be created.

Categories of KM frameworks identified by Lew *et al.* (2015) include foundation studies, a resource based view, information infrastructure capability, competitive advantage, and organisational information processing theory studies. Tacit knowledge characterised by "applied skills and learning-by-doing" impacts supply chain performance (Schoenherr et al., 2014, p.129) within a resource-based view (Barney, 1991). Some useful concepts are difficult to apply in CAD ports because priorities differ from Lew *et al.'s* (2015) focus on knowledge-based companies in Asia. Information infrastructure capability studies which identify creation of explorative knowledge out of tacit knowledge may assist ports where tacit knowledge is available. Where explicit knowledge is rare, exploitative knowledge generated from explicit knowledge capture prior to codifying (Abdel Aziz and Kamel, 2012) is academic. Remote ports with minimal internet connections are vulnerable if competitive advantage depends on information technology capability (Bharadwaj, 2000).

Sub-categories of "foundation studies" of KM frameworks include Nonaka's (1994) organisational knowledge creation model (discussed below), corporate memories as a KM tool, a knowledge strategy model, and KM and KM system models. To incorporate available explicit organisational knowledge in the "corporate memory" (Gertjan *et al.*, 1997) PSMS requires a taxonomy of sustainable MO to guide self-learning, to structure direct learning involving communication and indirect learning of stored knowledge. Each port requires a rudimentary knowledge strategy (Zack, 1999) but minimal resources and information technology competencies in CAD ports render architectural system design for managing technical data irrelevant. Alavi and Leidner's (2001) review of best practice sharing, creation of corporate memories and knowledge networks could guide a supra-port PSMS for SWRPA.

Nonaka (1994) observed four modes of exchange represented in a "SECI" (Socialization, Externalization, Combination, Internalization) framework applicable to the specialist context of product innovation. Within an organisation, ongoing exchange of ideas results in new knowledge being created dynamically (Nonaka, 1994; Schoenherr *et al.*, 2014). Tacit knowledge may be exchanged with explicit knowledge or vice versa. Where individuals jointly share tacit knowledge socially, new tacit knowledge may be created in a socialization mode of exchange. Where the output of exchanges of tacit knowledge is new explicit knowledge, externalization has occurred. In a combination mode of exchange, new explicit knowledge emerges as individuals exchange explicit knowledge which integrates and transforms their experiences. Finally, internalization occurs where exchanges of explicit knowledge result in learning and transformation into tacit knowledge (Nonaka *et al.*, 2001; Richtner and Ahlstrom, 2010).

This paper adopts the paradigm of a commercial HM, within which each new sustainable MO represents a new port "product". This view partially reconciles contextual variations between product innovation (Nonaka, 1994) and CAD ports. PSMS includes an iterative portfolio review, which involves continuous knowledge creation as new information is received, shared and exchanged. For these contextual reasons the SECI framework appears appropriate to guide PSMS design. At a process level, the information exchange processes identified in scoping studies also characterise a SECI formulation. During socialisation, physical proximity facilitates tacit knowledge creation as tacit knowledge is acquired through direct interactions; HMs share experiences at monthly SWRPA meetings and annual HM conferences. During HM conferences, technical meetings, and staff briefings externalisation is likely as tacit knowledge is translated into "metaphors, concepts, hypothesis, diagrams, models or prototypes" which enable others to make sense of it (ibid). Where reflections are inadequate, knowledge gaps may appear and facilitate interaction between individuals to fill them. Informal or round table interactions facilitate expressions of each individual's own tacit knowledge into "readily understandable forms". Within ports, explicit knowledge includes Harbour Orders, regulatory updates and guidelines which following implementation are "converging… into more complex and systematic explicit knowledge" which can be "exchanged and combined" (ibid). Existing knowledge is sorted, reconfigured, combined and categorised to create new knowledge involving "communication, diffusion and systematisation". Knowledge is created internally and externally, combined, disseminated amongst the members through presentations and edited to become usable. HMs regularly share best practice and visit other ports (Dinwoodie *et al.*, 2012). During internalisation, created knowledge is "shared throughout the organisation" by "embodying explicit knowledge into tacit", linked with "learning by doing" (ibid, p.17); education and training is a prime mission in most harbour authorities.

2.3 Tacit knowledge capture and industry

Because PSMS is a KM system to guide sustainable operations management, some findings from KM literature assisted PSMS design. Effective KM requires both knowledge of operations and specialist senior managers (Germain *et al.*, 1996). Giunipero *et al.,* (2006) suggested a link between sharing knowledge, improving productivity and reducing costs which is essential for sustainable MO. Service innovation impacts economic growth

(McDermott and Prajogo, 2012), and given that ports provide mostly operational services, knowing which areas to innovate in could boost economic activity. KM is essential to achieve quality improvement (Piercy and Rich, 2015), competitive advantage (Grant 1996), and sustainable competitive advantage (Li *et al.*, 2012; Jeffers, 2010). Effective sustainability management requires KM, and understanding of the environmental impacts of organisational operations impacts mitigation measures (Prajogo *et al.,* 2014). Similarly, sustainable competitive advantage demands succession planning for products and organization leaders. However, tacit knowledge is difficult to codify and make explicit, and to pass on to future generations of employees (Nonaka *et al.*, 2001).

Organisational processes which underpinned design of the SECI framework for new product development resemble those for designing PSMS. At each stage of knowledge creation, top management must emphasise explicit knowledge with a "positive effect on knowledge conversion" (Richtner and Ahlstrom, 2010, p.1022). Tacit knowledge capture is emphasised because routine "common and basic" organisational knowledge provides less competitive advantage than "unique and innovative" knowledge (Zack, 1999, p.55). KM must consider knowledge as both an object and a process, to facilitate innovation. Stage one of the methodology focuses on explicit knowledge, typically "common and basic" which is updated to remain current, relevant and applicable. In stage two, the SECI framework assists tacit knowledge capture and taxonomy development to guide PSMS design.

3. Methodology

3.1 Stage one: Ethnographic Content Analysis

In this study a constructivist paradigm of enquiry empowers researchers to adopt an ethnographic methodology to tap the meaning which HM practitioners ascribe to their accumulated experience of particular circumstances and events (Howell, 2013), especially where tacit knowledge capture engages specialist practitioners. As an inductive approach, ethnography demands that researchers immerse themselves within a real world ecological setting (Saunders *et al.*, 2015). This setting invites a research strategy to collate data in its ecological setting, within which subjects explain their social world in their own words. In the current context realist ethnography underpins participatory observational visits to HMs in port offices using interviews to tap individuals' conceptions of MOs and PSMS and report as factually as possible HMs' own accounts of their actions and perceptions.

Stage one includes capture of scarce explicit knowledge, content analysis (CA), and processes to ensure the replicability of methods. CA is an intellectual process to categorise qualitative data into conceptual categories or clusters to identify consistent patterns and relationships between variables or themes. Text is interpreted personally to reflect various meanings, and it becomes context dependent (Julien, 2008). In Bryman and Bell's (2011, p.291) definition CA seeks to "quantify content in terms of predetermined categories and in a systematic and replicable manner". In this study, predetermined categories were established deductively from a prior definition of MOs based within one specific port context (Dinwoodie *et al.*, 2012). Subsequently, ECA assisted categories to emerge from the data, whilst recognising the importance of understanding their meaning within the context in which items are based (Bryman and Bell, 2011, p.291).

ECA combines aspects of ethnographic research with CA systematically and analytically, but retains flexibility (Altheide, 1987) as items of data may be relevant for several purposes during coding. Krippendorf (2004, p.21) noted that ECA offers flexibility to allow new concepts to emerge during "involvement with texts" and although ECA is steered at first by variables and categories, other categories may emerge (Altheide, 1996, p.16). Concepts are developed, described and verified. In this study the quality, meaning and purpose of text extracts varied, requiring an understanding of how meaning is communicated. ECA offers a replicable approach to search databases and analyse shortlisted data by emphasising how contexts are discovered and explained, their fundamental meanings and the patterns and processes which link variables (Altheide, 2008).

3.1.1 Applying ECA to maritime operations

Comprehensive literature searches (see section 3.1.2) and Pattern Analysis of shortlisted sources using ECA (see section 4.1) generated a tentative taxonomy of MO with varying units of analysis. Multiple dimensions of thought create a taxonomy of concepts which reflects the position of notions within the network (Krippendorff, 2004, p.296). "Cargo handling" spans two distinct categories representing both an action, and an object if verbs are omitted. The concept is multidimensional, but understandable within an appropriate taxonomy of MO. Similarly, "bunkering operations" spans distinct marine and maritime dimensions. To assist the construction of meaning, ECA permits subdivision of one concept into multiple categories.

As a measure of intercoder reliability Cohen's kappa (κ) tests the variance between coders whereby if coders use categories in unequal frequencies their categorisations may become unreliable (Krippendorff, 2004, p.419). Krippendorff's alpha (α) allows for an unlimited number of coders and accounts for chance agreement, but is complex to calculate. Scotts' pi, κ, and α statistics revealed minimal statistical differences in intercoder reliability in comparative analysis of coded articles published in newspapers, magazines and media sources (Lombard *et al.,* 2002).

Research stage one aimed to verify a base definition of MOs through discovery (Table I). Commencing with six pre-structured categories (section 3.1.2) defined by academic theory (e), ECA assisted 44 new categories to emerge (f) through multiple entry points and continuous emergence of concepts (k). Multiple streams of information were acquired through primary and secondary data sources (i). These were validated, verified (e) and steered reflexively (b) by acquiring new data and developing new concepts. Textual information obtained from comprehensive academic literature searches (g) was analysed by two people and validated statistically (l) to ensure intercoder reliability. Narrative descriptions and comments were verified to validate findings (h, j). Finally, continuous updating of the tentative taxonomy with new categories, codes and concepts (d) generated useful findings. Tables (II, III, IV) show the methods of undertaking ECA (m).

Table I about here

3.1.2. Analysis of texts

Sources of explicit knowledge (to January 2012) were identified firstly through comprehensive index searches spanning journals, electronic and hard copy resources in a specialist university library. Secondly, keyword searching provided the sole shortlisting criterion using the keywords "MO", "port operations" and "marine operations" to embrace overlap or misuse of terminology. Keywords were varied between search fields to ensure clear distinctions between types of operations (Kuznetsov *et al.,* 2015). The "title" field guided a preliminary search successively using all three keywords. To boost low search yields, keywords were entered into “abstract” and “all text” fields, which sometimes generated unrelated data. Keywords such as “anchoring”, “bunkering”, “ballast water”, “ship” and “port” narrowed the results. Later searches deployed the keyword “operation” although some sources included double spacing. Physical examination of 3910 digital hits shortlisted 17 including nine from *Science Direct*, three each from *EBSCO* and *Metalib (Marine)* and two from *Palgrave Macmillan*. Journal sources included the *Journal of Transportation Research, Part A* (four), two each in *Maritime Policy and Management* and *Maritime Economics and Logistics* and one each in *Transportation Research D*, *Transportation Research E* and *Marine Pollution Bulletin*. Searches of local, international and supranational governing bodies and the ports industry for official documents revealed four texts and a physical library search generated two texts.

After sources had been shortlisted, Dinwoodie *et al.*’s (2012, p.111) base definition of port-specific MOs was used to analyse texts:

> “MOs span all routine procedures which a ship must undergo whilst in port to operate effectively, including anchoring, marine fuel bunkering and ballast water exchange.”

Six categories were identified spanning frequency (“routine”), action (“MOs”), object (“a ship”), timing (“whilst”), place (“in port”) and purpose (“to operate effectively”). These categories were used deductively to extract specific information from other sources to underpin a structured taxonomy. The length of one coding unit varied between one word (e.g. ship, port, cargo) and a whole phrase (e.g. to safeguard the environment). This approach symbolises using ECA to discover meaning and patterns (Altheide, 2008).

Table II lists all major categories (*A* to *F*) and sub-categories extracted from the literature with concepts shown as major categories. Each sub-category (*A1* to *F5*) represents a code to tag and group concepts; the frequency of use is shown.

Table II about here

Sub-categories *A1* to *F5* were aligned vertically in ascending order in SPSS, allocating one row per sub-category. The categories used for coding generated nominal scale data, excluding the use of reliability testing indices based on ranking methods. For each case, binary coding assigned “1” when a category was used and “0” otherwise. One column was assigned to each coder in each case study and intercoder reliability between two coders was tested using Crosstabs analysis and κ.

The computed estimates of intercoder reliability ranged between $0.828 <= \kappa <= 1.000$. For nominal scale data, SPSS computes Phi (φ) and Cramer’s V coefficients to test for reliability and given no apparent discrepancies between indices, κ was preferred, with $\kappa >= 0.90$ considered acceptable in all situations, and $\kappa >= 0.80$ in most situations (Lombard *et al.,* 2002). Calculated intercoder reliability was excellent, with full agreement on cases 1 and 4 ($\kappa = 1.000$). In case 2, coder A identified two additional codes (*C1a*, *C3*; $\kappa = 0.858$). Similarly, cases 3 and 5 showed minor disagreement ($\kappa = 0.918$ and $\kappa = 0.868$ respectively).

During coding the number of codes per source was unrestricted, enabling all concepts to emerge for both coders. After establishing reliability and agreeing a final set of codes for each definition, the next step aimed to discover patterns contained within the final set of codes to discover and verify theoretical relationships and provide a tentative definition. ECA’s orientation towards “concept development, data collection and emergent data analysis" (Altheide, 1987, p.17) requires comparative analysis of literature extracts for emerging concepts. Pattern Analysis of codes revealed few shortlisted sources which contained useful definitions because the quality of sources differed; the remainder included extracts ranging from several sentences to tables (see section 4.1).

3.2 Stage two: Testing the tentative definition of MO

In research stage two, semi-structured workplace interviews tested how accurately the tentative definition of MO reflected the diverse commercial revenue streams of smaller ports. Discussions captured tacit knowledge to clarify whether MOs were "routine", "commercial" or "environmental" to align practice with published definitions. Interviews were conducted between August 2012 and May 2013 and lasted between 73 and 190 minutes; two exceeded 120 minutes. Question ordering was varied to encourage natural conversation, and interviewees edited transcripts to enhance internal validity (see Kuznetsov, 2014: Table 6.4). After discussing respondents' understanding of MO within their port, questions probed how the impacts of MO were managed, port sustainability needs, and how these were managed. Questions explored the interviewee's operational role, MO undertaken locally and any potential environmental impacts. Requirements for environmental planning were discussed alongside port development plans, potential environmental impacts, and processes deployed for managing them. The nature and scope of environmental management systems used was discussed alongside the processes of devising and administering them, and attitudes towards them. Questions investigated interviewees' operational responsibilities for managing safe navigation, environmental impacts, budgets available, fitness for purpose and evaluated the strengths and weaknesses of current provisions. Next, interviewees outlined the main sustainability needs of their port; how these were managed; the systems, resources and training required to manage their needs more effectively; system benefits, requirements, costs and barriers to implementation. Potential interest in a PSMS was discussed before exploring the port's focus, role and profitability; key stakeholder issues; how commercial customers' needs are prioritised; successful local community initiatives, and any other relevant issues.

Sampling design to tap specialist knowledge to identify representative interviewees was influenced by maritime governance in CAD involving 41 harbour authorities, with up to four authorities overseeing one estuary. A snowball sampling strategy engaged Devon's Coastal Officer and Cornwall's Maritime Manager who oversee municipal ports in each county. However, because both are detached from day-to-day MO the substantive content of interviews with them was discarded. Their suggestions for sample selection were supplemented by recommendations from SWRPA ensuring full representation of differing governance structures, mission statements, environmental designations, revenue streams and operational scope, to facilitate generalisation and theory building. Interviewees represented five estuaries and two bays including HMs in four trust and two municipal ports, a Deputy Harbour Master (DHM), an Operations Manager (OM) and one of CAD's two specialist Environmental Managers (EM). To respect their anonymity nine interviewees are classed as: HM1…HM6, OM, DHM, EM (Kuznetsov, 2014: Tables 6.4, 6.5); seven are cited. Interviewing ceased when additional interviews generated no new concepts.

4. Results

4.1 Stage one: Pattern Analysis

Stage one research proceeded to establish a base definition using a reliable set of categories and agreed codes for each definition (see Section 3.2.1 and Table II). Literature extracts for each emerging concept were compared to discover matching patterns of concepts, and to discover and verify theoretical relationships (Altheide, 2008). In Table II, concept code *B2* represents concept "MO". Ten patterns of matched concepts (*p=p1, p2…p10*) were used by different authors. Table III shows how many times each concept was used, and the total number of times each concept of MO was coded in prior literature, to ascertain theoretical links between MO to update a definition.

Table III about here

In pattern *p1*, concept code *A1* is matched with *B2* and *E1* which can be highlighted visually. In Figure 1 each row summarises chronologically the shortlisted existing definitions ("sources") using the agreed concept codes. Rows 1, 2 and 5 depict pattern *p1* where in all three instances, concept code "routine" matches "MO" and "port location". In Table III, "*B2*+*E1*+*A1*=3" for pattern *p1* shows that this exact combination of codes was found three times in the shortlisted sources. "Total number of uses" shows the number of times that each code was found independently.

Fig. 1 about here

Similarly, returning to Table 3, for pattern *p2*, the concept "during" matches "MO" and "port location"; "environmental purpose" matches "MO" and "port location" (*p3*); "routine" and "during" are matched with "port location" (*p4).* The process continues until a tentative explicit taxonomy emerges.

The base definition of MO was port-specific but following Pattern Analysis a more comprehensive tentative definition emerged as: *"MOs comprise all routine procedures which ships and vessels undertake for commercial and environmental purposes whilst in port"*.

4.2. Stage two: tacit knowledge capture

Semi-structured interviews (see Section 3.2) captured tacit knowledge to test the tentative definition of MO. Numerous operational similarities were identified, along with new MOs which varied with port size, physical location, physical conditions defined by areas safeguarded by environmental legislation, revenue streams, governance model, community relations and stakeholders. HM4 receives limited revenue streams and undertakes in-water surveys, hull surveys and scrubbing operations in a sheltered anchorage, saving clients the expenses and booking queues associated with dry-docks (HM1, HM4, DHM). Ship lay-ups whilst vessels await orders were mentioned by each participant, but this operation is commercially important to HM2 who hosts a deep water anchorage. Other MOs include water-taxi services which ferry crew ashore during lay-ups. Alternatively, passenger transfers reduce road vehicle movements, associated atmospheric emissions and road congestion. "Coast hopping" of heavy equipment between sheltered anchorages during fine weather windows, generates water dues for HM4. Prior academic literature had overlooked winter stowage operations associated with stowing unused craft, which generated revenues from rentals and user-charges for specialist handling equipment (HM1, HM4). Pilotage is both a commercial operation and a mandatory safety requirement for some harbours (HM1, OM), depending on the depth of available navigable channel for certain vessel sizes and difficulty of navigation (DHM). Unsurprisingly, OM identified MOs which included the management of pilotage contracts, ensuring how pilotage is provided, compliance with the Pilotage Act, regular crew training and the suitability of vessels for pilotage operations. HM1 identified MOs as the “essence of trade” and “all the stuff that makes commerce work”, embellished by HM2 as “commercial, for example loading and offloading” and HM3 as “everything to do with providing facilities and running harbours, and everything involved in that”.

4.2.1 Links with sustaining operations in ports

The commercial purpose of MOs identified in stage one and verified in stage two implies a PSMS designed to safeguard MOs proactively, to unlock port resources and business opportunities. Benefits generated include savings of HMs’ time, better stakeholder relations and reduced consultants’ fees (Kuznetzov et al., 2015). HMs have to account for their actions to stakeholders and governing bodies even if some port stakeholders sometimes view safety and other functions as non-commercial (HM1). Similarly, errors arise if environmental management is conceived as an administrative process divorced from commercial activities. If HMs are reproached this may damage some commercial activities. Reactions involving sudden investments are costly and a bad reputation takes time to redeem (HM1, EM). A PSMS grounded in practical experience and industry research promises competitive advantage, generating potential monetary benefits estimated at GBP50kpa per port, or GBP3.86M aggregated over 5 years in 15 participating ports (ibid).

Sustainable MO underpin efficient international trading systems but scant prior knowledge about diverse smaller ports challenge companies seeking to enter local supply chains to develop business opportunities. Opportunities for more ports to develop commercial operations and new supply chains arise from increasing volumes of shipped cargo and heightened environmental concerns. HM1’s comment that “…decisions should be made on the best available knowledge, in the absence of [which]… supposition and precaution is applied” (HM1, May 2013) corroborates an earlier observation that “I don’t think people understand ports” (Interview with EM, April 2013). Ports must focus on revenue streams which keep them operational. This knowledge determines whether ports proactively seek to develop diverse supply chains and safeguard commercial revenue streams or to reactively conserve existing trades and eschew new cargos and supply chain opportunities.

4.3. Maritime operations defined

A final taxonomy successfully represents MOs in a comprehensive listing that incorporates explicit and tacit knowledge (Table IV). Published MOs are retained to prevent data elimination and researcher bias. The taxonomy defines operational categories logically where for example “cargo related services” include “general” operations, and operations specific to on-shore and on-ship activities. Coding conventions are retained across Tables II and IV to ensure consistency. One category defines the “people involved” encompassing all actors in port who make commerce possible, spanning cargo services, and MOs overall (*B2c4*, Table IV). A “drivers” category shows the rationale behind MOs in case the taxonomy is incomplete, empowering larger ports to identify sub-categories and develop the taxonomy.

The taxonomy provides knowledge of the types of commercial operations that occur in ports, which may entwine dedicated supply chains involving spare parts, information services and raw materials. For example, hull surveys and hull scrubbing at anchor (points *B2p* and *B2q*, Table IV) require specialists to inspect vessels anchored in port, thereby creating employment, and specialist equipment purchased or delivered by a third party. The level of local employment generated depends on the nature and size of the job. Winter stowage operations (point B2s, Table IV) require hiring of specialist cranes and equipment, in turn involving users who rent warehouse space to store boats. Services are commonplace, based on equipment rental or ownership of forklifts and cranes. Existing literature omitted winter stowage, creating a gap in understanding between port operations and revenue streams. This operation presents warehouse logistics operators and mooring chain providers with new business and employment opportunities, where one port may host 2000 leisure vessels (HM1; HM4).

Table IV about here

The final taxonomy interlinks ports with production systems because people involved in running a port (*B2c4,* Table IV) are integral to efficient MOs and disputes cause severe disruption in production and supply chains. A holistic approach to managing port sustainability involves all MOs in ports engaging people, contracts and the prevention of disputes. Renewable energy also links ports with production systems, as ports increasingly become bases for energy production (BEPPo, 2015). Within CAD one port generated income by leasing space to renewable energy companies to test their devices. The process of leasing a section of water (category *B2v*) relates to running the harbour and the proceeds are commercial (*B2j*). Neither MO has been identified previously, but given the importance of renewable energy, innovative KM in ports to facilitate development of such devices and production of renewable energy is strategically important for energy security and sustainable development. Such MOs are routine operations within one specialist port, and other leasing operations are routine management procedures elsewhere in CAD. In this research "non-routine" MO were typically related to scale or local operational variation, but procedures to guide infrequent coast-hopping of large jack-up rigs still mimic frequent coast-hopping of small yachts, although this issue may invite further research. Now that MOs have been successfully represented in a taxonomy, Section 5 considers the implications.

5. Conclusions and implications

This research generated two main outputs. Firstly, a new final taxonomy of MO emerged that will support HMs in developing sustainability strategies. Secondly the paper presents a methodology that could be applied in both maritime and other contexts where operations depend on tacit knowledge held by key stakeholder groups. The implications of this work are that the taxonomy offers guidance in sustainability strategy formulation.

5.1 Implications for practice

The first outcome of this work is a new final taxonomy of MO grounded in comprehensive explicit knowledge in research stage one. The implication of this is a checklist of MO to guide sustainability management strategy in any port. However, applications to sustainability management in larger or more distant ports are exploratory because tacit knowledge capture in stage two occurred in CAD.

The second outcome related to a novel methodology, applicable where operations depend on tacit knowledge held by key stakeholder groups; this is potentially widely applicable to guide sustainability management strategy. The methodology offers the potential for organisations, industries or networks to gain sustainable competitive advantages. The methods presented assisted practical identification and definition of critical operations. When prioritized and safeguarded the methods articulate sustainability management strategies into sustainable operations management.

In research stage one, ECA added, combined and categorised existing explicit knowledge of MO to create a tentative taxonomy embodying new explicit knowledge. Contact with a researcher with wide access to explicit knowledge sources is recommended for replications in other sectors. The researcher will define specialist operations by conducting systematic database searches to capture available explicit knowledge, before refining the tentative taxonomy in stage two to incorporate tacit knowledge captured using the SECI framework. The methodology offers an effective process to capture organisational knowledge in contexts where long term corporate survival hinges on securing organisational succession in products and leadership, and explicit knowledge is scant.

Future applications would benefit from results-sharing within the project team to internalise new knowledge, substantiated by Pattern Analysis to facilitate tacit knowledge creation by embodying actions to capture the dimensions of strategy and tactics. In this study, SWRPA facilitated socialisation, observations and group discussion, and sharing of HM experiences transferred individual tacit knowledge freely between participants. Port visits assisted practical observation and tacit practitioner knowledge capture through direct contact and observation. Knowledge was externalised as HMs expressed ideas and used examples to demonstrate their point, later translated into reflective concepts to fill the knowledge gap. The resulting final taxonomy of MO incorporates explicit and tacit knowledge.

5.2 Implications for theory

This paper contributes to exploratory port sustainability management research and potentially other sectors where no reliable taxonomy of operations is available. In project stage one, a novel methodology for taxonomy development is presented based on the systematic selection, analysis and capture of published text, guided by ECA, in a sector lacking explicit knowledge. Supported by a tentative taxonomy of MO, the SECI framework facilitated new knowledge creation in stage two as concepts were refined, and key operational categories were identified and embellished. Working within CAD ports, successful capture of HMs' tacit knowledge in socialisation mode identified new MOs which must be safeguarded proactively to ensure local port survival.

Successful deployment of ECA to guide exploratory research analysed secondary data concerning sustainability in an industry where explicit knowledge is scant and theoretical development trails applications. ECA is flexible and incorporates sufficient quantitative verification to guide exploratory taxonomy development in other sectors. ECA is accessible to small organizations with insufficient resources to undertake bespoke research into operations but where knowledge drives innovation and competitive advantage. Additional primary data collection would attempt to capture the expertise, intuition and know-how of experienced employees and embed it into organisational development. This combination of methods can be applied to analyse unstructured, scarcely available secondary data to enhance understanding of limited knowledge and facts.

This paper represented port sustainability management as an iterative organisational KM portfolio review problem contextually suited to SECI formulation whereby each MO is analogous to a port "product". The SECI focus on dynamic knowledge creation suits PSMS design in process terms because new knowledge is created continuously as information is received and exchanged by HMs. Other KM frameworks offer useful concepts and procedures, but SECI framed many practical HM information exchange processes involving socialisation, externalisation and combination modes. Individual sustainability practice assumes that harbour users and employees display behaviours shaped by tacit knowledge acquired through education and training which assists them to internalise regulations.

5.3 Directions for future research

The methods presented suit operational contexts where practitioner knowledge to guide managers in planning more sustainable operations remains uncaptured. The process guide is replicable and transferable and will help to establish a theoretical background where explicit knowledge is scant, but may generate redundancy and duplication where an explicit base taxonomy of operations is widely accepted. Methods are accessible to support small companies searching within practitioner databases and researchers undertaking secondary data analysis to create ad hoc bespoke taxonomies. Interesting issues remain unresolved relating to the statistical validation of taxonomies where information is limited in quantity, structure and scope, with no single agreed statistical measure of inter-coder reliability. Ideally if explicit knowledge is well-established, proposals of base taxonomies of specialist sustainable operations in other industries would deploy a deductive approach but if not, they might abduct relevant data, or use methods presented in this paper. Later, capture of tacit practitioner knowledge will assist formulation of proactive strategies to enhance the sustainability of operations. The SECI framework assists filling of knowledge gaps to devise final taxonomies of sustainable operations.

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Study characteristic	Characteristics of ECA as deployed in:	
	Altheide (1996)	This project
(a) Research goal	Discovery, verification	Verification of definition
(b) Reflexive research design	Always	Yes
(c) Emphasis	Validity	Validity, verification
(d) Progression from data collection, analysis, interpretation	Reflection, circular	Continuous – circular, constantly updating data
(e) Primary researcher involvement	Purposive and theoretical	Theoretical
(f) Pre-structured categories	Some	6 pre-structured; 44 emergent
(g) Training required to collect data	Substantial	Search existing literature in academic databases
(h) Type of data	Narrative; numbers	Narrative and numbers
(i) Data entry points	Multiple	Multiple
(j) Narrative description and comments	Always	Yes
(k) Concepts emerge during research	Always	206 concepts emerged.
(l) Data analysis	Textual; statistical	Textual, and Cohen's Kappa
(m) Data presentation	Tables and text	3 tables: search results; taxonomy; data analysis

Table I
Characteristics of an ECA. Source: Adapted from Altheide (1996)

Major category	Sub category/code (A1:F5) and number of times used [3].
A. Frequency	*A1*) Routine [3]; *A2*) Exceptions(non-routine) [2]; *A2a*) Special conditions [1] *A3*) On-going [1];
B. Action	*B1*) Port Operations [12], *B1a*) Container Port Operations [3], *B1b*) Port Operation System [1]; *B2*) Maritime Operations [7]; *B3*) Marine Operations [3]; *B4*) Conservancy [12]; *B5*) Value Adding [2]; *B6*) Services To Cargo [10], *B6a*) on shore [4], *B6b*) on ship [1]; *B7*) Environmental Management [2]; *B8*) Construction [2]; *B9*) Shipping Operations [2]; *B10*) Port Activity [3]; *B11*) Impact [1].
C. Object	*C1*) Marine Craft [1], *C1a*) ships/vessels [9], *C1b*) other marine craft [1]; *C2*) Information Flow [2]; *C3*) Environment [1]; *C4*) Cargo [6]; *C5*) Finance [4]; *C6*) Business Environment [7]; *C7*) Inland Port Objects [5].
D. Timing	*D1*) While/During [3]; *D2*) Normalised [1]; *D3*) In The Near Future [1].
E. Where	*E1*) Port [14]; *E2*) Coastal and Marine environment [4]; *E3*) Sea Voyage [3]; *E4*) Inland [4]; *E5*) Ship/Shore Interface [1].
F. Purpose	*F1*) Commercial [10]; *F2*) Educational [0]; *F3*) Environmental [6]; *F4*) Safety [3]; *F5*) Organising and Operating [5].

Table II
A segment of the full taxonomy based on existing literature

Pattern	Frequency of concept use by different authors	Total number of uses
p1	MO (*B2*) + Port (Location *E1*) + Routine (Frequency *A1*) = 3	7+14+3
p2	MO (*B2*) + Port (Location *E1*) + During (when *D1*) = 3	7+14+3
p3	MO (*B2*) + Port (Location *E1*) + Purpose (Environmental *F3*) = 3	7+14+6
p4	MO (*B2*) + Port (Location *E1*) + Routine (Frequency *A1*) + During (When *D1*) = 2	7+14+3+3
p5	MO (*B2*) + Port Operations (*B1*) + Port (Location *E1*) + Ship (Object *C1a*) = 3	7+12+14+9
p6	MO (*B2*) + Port Operations (*B1*) + Port (Location *E1*) = 4	7+12+14
p7	MO (*B2*) + Conservancy (Operations *B4*) + Port (Location *E1*) = 2	7+12+14
p8	MO (*B2*) + Port Operations (*B1*) + Ship (object *C1a*) + Port (Location *E1*) + Purpose (Commercial *F1*) = 2	7+12+9+14+10
p9	MO (*B2*) + Port (Location *E1*) = 6	7+14
p10	MO (*B2*) + Ship (Object *C1a*) = 4	7+9

Table III
Pattern analysis

Categories of Maritime Operation: in port, cargo related, and by people involved, and by driver
In Port
B2a) Anchoring; *B2b*) Bunkering; *B2c*) Ballast Water exchange; *B2d*) Naval refuelling; *B2e*) Amphibious landing; *B2f*) Operation with autonomous underwater vehicles; *B2g*) Fuel supply; *B2h*) Movement from ship to ship; *B2i*) All human activities related to the sea; *B2J*) Commerce of the port; *B2k*) Efficient management of throughout of goods; *B2l*) From the inland connection to the port; *B2m*) Ship lay-up; *B2n*) Shipping related (tugs, tows, barges); *B2o*) In-water surveys; *B2p*) Hull surveys; *B2q*)Hull scrubbing at anchor; *B2r*) Coast hopping (for weather windows); B2s) Winter stowage; B2t) Shipping related services (e.g. water taxi); *B2u*) Management of pilotage contracts; *B2v*) Everything to do with providing facilities and running harbours, and everything involved in that
Cargo Related
B2a1) Handling; *B2b1*) Processing; *B2c1*) Security; *B2d1*) Loading; *B2e1*) Unloading; *B2f1*) Discharging; *B2g1*) Consolidation; *B2h1*) Distribution; *B2i1*) Break bulk
Cargo Related (On shore)
B2a2) Stevedoring; *B2b2*) Storage; *B2c2*) Reception; *B2d2*) Crane operations; *B2e2*) Getting cargo on the road; *B2f2*) Getting the right road connection; *B2g2*) Security;
Cargo Related (On Ship)
B2a3) Delivery; *B2b3*) Receipt;
People Involved
B2a4) Stevedores; *B2b4*) Cargo Supervisors; *B2c4*) People who work for commercial aspects;
Drivers
B2a5) The way you discharge your ship; *B2b5*) Commercial objectives; *B2c5*) All that makes commerce work; *B2d5*) Essence of trade; *B2d6*) Environmental benefit by taking cars off the road

Table IV
Maritime Operations Defined

Source	*Codes representing agreed concepts found in each source*								
1	*A1*	*B2*	*C1a*	*D1*	*E1*	*F5*			
2	*A1*	*B2*	*B4*	*B8*	*B11*	*D2*	*E1*	*F3*	
3	*B3*	*B4*	*C1*	*C1a*	*C6*	*E2*	*F3*	*F4*	
4	*B2*	*C3*	*F5*						
5	*A1*	*A2*	*B1*	*B2*	*B6a*	*B9*	*C4*	*D1*	*E1*	*F3*

Figure 1
Visual illustration of pattern *p1* from Table III