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SUSTAINABILITY IN THE SPANISH PORT SYSTEM: A QUANTITATIVE APPROACH

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SUSTAINABILITY IN THE SPANISH PORT SYSTEM: A QUANTITATIVE APPROACH

D. Federico Martín Bermúdez.

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En Santiago de Compostela a 21 de Abril de 2020

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SUSTAINABILITY IN THE SPANISH PORT SYSTEM: A QUANTITATIVE APPROACH

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En Santiago de Compostela, a 21 de Abril de 2020

Asdo. Eva Aguayo Lorenzo

Asdo. Fernando González Laxe

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A mi familia,

Y a Candy, siempre.

Summary

The Spanish port system includes 46 ports of general interest, managed by 28 Port Authorities and coordinated by the public entity Puertos del Estado (Ports of Spain). Spanish ports are very important economic hubs: state port system activity accounts for 1.1% of the GDP of Spain and 20% of the GDP of the transport sector. The cargo moving through their facilities accounts for more than 50% of Spain's foreign trade with the European Union and 90% of trade with third countries.

2010 witnessed an important milestone: the passing of a new Port Law (Law 33/2010) with a strong commitment to sustainable development. Consequently, the Spanish port system for ports of general interest is the only one in the EU that, due to legal standards, endorses the principles of sustainable development and regulates the specific environmental management duties for the Port Authorities.

Since this standard passed, every Spanish port has drawn up a mandatory annual Sustainability Report accounting for their commitment to sustainable development through a panel of 111 indicators. Based on the data provided by said Report, and for the period covering 2010 to 2016, this dissertation *Sustainability in the Spanish port system; a quantitative approach*, analyses the performance of the ports and their commitment to sustainability from two perspectives: the first, from a multidimensional point of view, through a contribution entailing the application of a synthetic sustainability index for a specific group of ports (in this case, those specialising in the transport and processing of liquid bulk cargo). And, secondly, from a port environmental performance standpoint, through two contributions regarding the institutional government and management on two characteristic port issues: air and noise pollution, also introducing for this last case an institutional component, as the role of the stakeholders in the port governance in this area is analysed.

Resumen

El sistema portuario español de interés general está compuesto por 46 puertos, gestionados por 28 Autoridades Portuarias y coordinado por el organismo público Puertos del Estado. Los puertos españoles son núcleos de gran importancia económica: la actividad del sistema portuario estatal aporta el 1,1% del PIB de España y el 20% del sector del transporte. Las mercancías que se mueven en sus instalaciones representan más del 50% del comercio exterior español con la Unión Europea y del 90% con países terceros.

En el año 2010 tiene lugar un hito transcendental: la aprobación de una nueva Ley de Puertos (Ley 33/2010) con una apuesta decidida por el desarrollo sostenible. Es por ello que el sistema portuario español de interés general es el único caso en la UE que, por normativa legal, asume los principios de la sostenibilidad y regula las obligaciones concretas para las Autoridades Portuarias en materia de gestión ambiental.

Desde la promulgación de dicha norma, cada uno de los puertos españoles elabora anualmente una Memoria de Sostenibilidad, donde refleja de forma obligatoria su compromiso con el desarrollo sostenible a través de un panel de 111 indicadores. Partiendo de los datos aportados por dichas Memorias, y para el periodo comprendido entre 2010 y 2016, la presente Tesis Doctoral (*Sostenibilidad en el sistema portuario español: un enfoque cuantitativo*), analiza el desempeño de los puertos y su compromiso con la sostenibilidad desde dos perspectivas: la primera de ellas desde un punto de vista multidimensional, a través de una aportación consistente en la aplicación de un índice sintético de sostenibilidad para un determinado conjunto de puertos (en este caso los especializados en tráficos y procesado de graneles líquidos). Y, en segundo lugar, desde el punto de vista del desempeño portuario ambiental, mediante dos aportaciones en torno a la gobernanza y gestión institucional sobre dos problemas característicos de los puertos: la contaminación atmosférica y la acústica, introduciendo además para este último caso una componente institucional, al analizar el papel de los stakeholders en la gobernanza portuaria en esta materia.

Resumo

O sistema portuario español de interese xeral está composto por 46 portos, xestionados por 28 Autoridades Portuarias e coordinado polo organismo público Portos do Estado. Os portos españois son núcleos de grande importancia económica: a actividade do sistema portuario estatal achega o 1,1% do PIB de España e o 20% do sector do transporte .As mercadorías que se moven nas súas instalacións representan máis do 50% do comercio exterior español coa Unión Europea e do 90% con países terceiros .

No ano 2010 prodúcese un feito transcendental: a aprobación dunha nova Lei de Portos (Lei 33/ 2010) que aposta de forma decidida polo desenvolvemento sustentable. É por iso que o sistema portuario español de interese xeral é o único caso na UE que, por normativa legal, fai seus os principios da sustentabilidade e regula as obrigas concretas para as Autoridades Portuarias en materia de xestión ambiental.

Dende a promulgación de dita norma, cada un dos portos españois elabora anualmente unha Memoria de Sustentabilidade, onde se reflicte de xeito obrigatorio o seu compromiso co desenvolvemento sustentable mediante un panel de 111 indicadores. Partindo dos datos que achegan esas Memorias, e para o período comprendido entre 2010 e 2016, a presente Tese de Doutoramento (*Sustentabilidade no sistema portuario español: un enfoque cuantitativo*) analiza o desempeño dos portos e o seu compromiso coa sustentabilidade dende dúas perspectivas: a primeira delas dende un punto de vista multidimensional, a través dunha contribución consistente na aplicación dun índice sintético de sustentabilidade para un determinado conxunto de portos (neste caso os especializados en tráficos e procesado de graneis líquidos). E, en segundo lugar, dende a perspectiva do desempeño portuario ambiental, mediante dúas achegas en torno á gobernanza e xestión institucional sobre dous problemas característicos dos portos: a contaminación atmosférica e a acústica, introducindo ademais para este último caso unha compoñente institucional, ao analizar o papel dos stkeholders na gobernanza portuaria.

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RESUMEN

El sistema portuario español de interés general comprende 46 puertos, integrados y gestionados por 28 Autoridades Portuarias que dependen del organismo público Puertos del Estado. En el año 2018 por sus instalaciones pasaron 46 millones de pasajeros y más de 174.000 buques mercantes y de pasaje. Con una cifra de negocio de 1.157 millones de euros y un beneficio consolidado de 307 millones, el tráfico de mercancías alcanzó los 563,5 millones de toneladas, movidas en una superficie disponible de más de 10.200 hectáreas de área de servicio. Adopta el modelo Land Lord Avanzado de gestión, en donde las Autoridades Portuarias no prestan servicios comerciales ni portuarios, los cuales son llevados a cabo por operadores privados con sus propios medios humanos y técnicos. Las Autoridades Portuarias proveen de espacio e infraestructuras a dichos operadores y regulan su actividad.

Por otro lado, en la década de los 90 del pasado siglo comenzaron llevarse a cabo iniciativas destinadas a aplicar e impulsar los principios de la sostenibilidad en los sistemas portuarios, en concordancia con el impulso del nuevo paradigma del desarrollo sostenible que había sido abordado oficialmente en la década inmediatamente anterior.

Tales experiencias culminarían en el año 2010 con un hito transcendental en el sistema portuario español: la aprobación de una nueva Ley de Puertos (Ley 33/2010) en donde se recoge una apuesta decidida por el desarrollo sostenible. Específicamente, se asume un compromiso claro con la sostenibilidad, ya que obliga a las Autoridades Portuarias a que, dentro de los Planes de Empresas que anualmente deben llevar a cabo, se recojan los objetivos e indicadores de sostenibilidad ambiental del puerto, así como una adenda en forma de Memoria de Sostenibilidad que deberá elaborarse de acuerdo con una metodología propia.

Con este mandato, Puertos del Estado procede a alumbrar esa Metodología específica para realizar las Memorias de Sostenibilidad en las Autoridades Portuarias, adoptando la versión integral y multidimensional del desarrollo sostenible. Esta apuesta legislativa y metodológica es una actuación novedosa, ya que no existe en España ninguna normativa parecida para organismos y empresas estatales de similar tenor, lo que dota a estas organizaciones de una herramienta de planificación para el análisis, diagnóstico y fomento del desarrollo sostenible.

La información derivada de las bases de datos que se han construido en la investigación con la explotación de las 111 variables que conforman las Memorias de cada puerto y para todos los años analizados, constituye una fuente fundamental para llevar a cabo la presente Tesis Doctoral "Sostenibilidad en el sistema portuario español: un enfoque cuantitativo"; adopta el formato de *compendio de artículos de investigación*, regulado en el Artículo 41 del Reglamento de Estudios de Doctorado de la Universidade de Santiago de Compostela aprobado por el Consello de Goberno el 12 de junio de 2017 y publicado en el DOG nº 143 de 28 de julio de 2017. En este sentido, la Tesis está compuesta por tres aportaciones, publicadas en revistas indexadas en las listas correspondientes de SCI (Science Citation Index) o SSCI (Social Science Citation Index). Todas ellas se encuentran incluidas en el Journal Citation Report (JCR) y, simultáneamente, en el Scimago Journal Rank (SJR/Scopus).

Las contribuciones que la conforman llevan una línea metodológica común, forman una unidad de investigación y presentan coherencia temática. Algunas de las razones que justifican esta afirmación serían:

1. En primer lugar, como se ha señalado, se parte de una fuente de información común, única y original, elaborada ad hoc para la investigación plasmada de forma particularizada en cada una de las tres publicaciones. Se ha generado por tanto una

base de datos exclusiva y única para llevar a cabo la investigación que dio lugar a las aportaciones presentadas.

2. En segundo término, además de partir de una información única y original, las tres contribuciones se realizaron sobre el mismo objeto de estudio: los puertos españoles de interés general y sobre idéntica temática: la sostenibilidad portuaria.
3. Por último, la presente Tesis Doctoral trata de contribuir con algunas novedades:
    - En la primera de las aportaciones se aplica una metodología diseñada al efecto, consistente en la construcción de un índice sintético para su aplicación a la sostenibilidad portuaria.
    - La investigación llevada a cabo con el planteamiento anterior, concluyó con un resultado significativo: durante el período analizado, la dimensión medioambiental se presentaba como la más estable para los puertos estudiados. Este hecho sugería investigar las razones de tal comportamiento. Siguiendo las preocupaciones ambientales de los principales puertos europeos, se seleccionaron las dos prioritarias: contaminación atmosférica y acústica. A este hecho se unía otro no menos importante ya que, en su mayoría, los puertos españoles se encuentran ubicados en entornos urbanos. Tal circunstancia incide en las relaciones puerto – ciudad y dota de singular relevancia a la influencia de la calidad del aire y la generación de ruidos en la población como consecuencia de las actividades portuarias. De ahí, que la operativa de estas dos aportaciones parta de la base de datos generada (en este caso de la correspondiente a los 35 indicadores de desempeño ambiental de las Autoridades Portuarias), de los cuales se seleccionaron los relativos a cada una de las fuentes de contaminación a explorar, con las especificaciones metodológicas que se detallan en cada una de ellas.

Aunque, como es obvio, en cada aportación se recogen con detalle los objetivos de investigación, pueden resumirse como objetivos generales de la Tesis los siguientes:

1. Llevar a cabo un análisis empírico de la sostenibilidad en el sistema portuario español. Todo ello desde un enfoque de gestión tanto por parte de Puertos del Estado, como particularmente para cada una de las Autoridades Portuarias.
2. Constatar si la aplicación de las estipulaciones contenidas en la Ley de Puertos en materia medioambiental ha supuesto un impacto positivo en el control y desarrollo de estrategias para la reducción de emisiones contaminantes en los puertos españoles de interés general.

Éstos pueden complementarse con una serie de objetivos específicos, tales como:

1. Constatar, desde la perspectiva del desarrollo sostenible, los cambios habidos en las Autoridades Portuarias españolas con instalaciones especializadas en la importación y refino de petróleo entre los años 2010 y 2015, coincidentes con la crisis económica global y examinar las sendas que han seguido dichos puertos desde la óptica de la sostenibilidad, entendiendo ésta en su concepto integral y multidimensional.
2. Verificar si la aplicación de las estipulaciones contenidas en la Ley de Puertos en materia medioambiental ha supuesto un impacto positivo en la reducción de emisiones a la atmósfera en los puertos españoles de interés general, analizar la evolución de las medidas de control e identificar las prioridades.
3. Identificar los focos de ruido que se producen en los puertos y averiguar las estrategias y actuaciones seguidas para mitigar la contaminación acústica.
4. Concretar la influencia del tamaño de los puertos en la problemática derivada de la sostenibilidad portuaria.

5. Analizar la percepción del desempeño ambiental de las Autoridades Portuarias por parte de los stakeholders y su influencia en la toma de decisiones.

Por otro lado, independientemente de los aspectos metodológicos comunes para todas las aportaciones a los que se ha hecho referencia anteriormente y las particularidades que se incluyen en cada publicación, para la elaboración de la presente Tesis Doctoral como se ha señalado, se ha partido de la información relativa a los 111 indicadores que se contienen en las Memorias de Sostenibilidad elaboradas por las Autoridades Portuarias españolas y clasificados según las cuatro dimensiones del desarrollo sostenible.

En lo que respecta a la elaboración del *índice sintético de sostenibilidad portuaria*, recogido en la primera de las publicaciones, se ha seguido una metodología específica y la selección de variables para el periodo estudiado (2010-2015) obedece a la necesidad de contar con datos homogéneos que permitan analizar el desempeño portuario desde una perspectiva multidimensional**.** En el año 2010, las Memorias de Sostenibilidad mantenían diferencias sustanciales en la metodología del reporte de los datos con las que se llevarían a cabo posteriormente, ya que distinguían entre dos tipos de indicadores: de carácter optativo y prioritario. Es por ello que dentro del conjunto de Autoridades Portuarias y más concretamente dentro de la submuestra elegida, (puertos especializados en graneles líquidos), tan solo seis de ellos presentaban datos completos y coherentes para llevar a cabo la investigación del total de ocho que estarían incluidos en esta muestra. En consecuencia, a partir de la base de datos generada se obtuvieron y seleccionaron 48 variables perfectamente equivalentes y homogéneas que se agruparon según las cuatro dimensiones del desarrollo sostenible (económica, institucional, social y ambiental), clasificadas en 11 indicadores y 22 subindicadores.

Para el desarrollo de la investigación de las dos últimas aportaciones, que analizan el *desempeño portuario desde la perspectiva ambiental,* se comenzó con la selección de los indicadores representativos de dos de los problemas de gestión portuaria más relevantes: calidad del aire y ruidos: Estos indicadores presentan una estructura consolidada y homogénea para los años 2011-2016.

Para la primera de las aportaciones, en este caso la referente a la *contaminación atmosférica* se parte de la información del indicador A7 de las Memorias (medidas implantadas para mejorar la calidad del aire). Este indicador admite 20 respuestas diferentes, compuestas a su vez por tres posibles alternativas: 8 mediadas de carácter Administrativo, 6 de carácter Operativo y Técnico, y 6 de actuaciones con Técnicas Específicas. Con dicha información se construyó una matriz de 20 x 28 para cada año de reporte, lo que permite procesar un total de 3.360 respuestas, recodificarlas y jerarquizarlas estadísticamente. Además del análisis global, se lleva a cabo una investigación particularizada segmentando los resultados por el tamaño de los puertos, en base a los criterios de clasificación más relevantes.

La siguiente prioridad en sostenibilidad ambiental que se analiza en la presente Tesis es la relativa a la contaminación acústica en los puertos españoles de interés general. La información contenida en las Memorias de Sostenibilidad relativa a los indicadores de ruido es más compleja y amplia, lo que requiere el uso de diversas matrices de información según se describe a continuación siguiendo el orden llevado a cabo en la investigación. El primero de los indicadores utilizado A18 (identificación de fuentes de ruido). Admite la identificación de 10 posibles fuentes de contaminación acústica con 5 niveles de incidencia; el indicador A21 (actuaciones y medidas sobre los focos de ruidos) de forma análoga a los contenidos reflejados en el indicador de calidad del aire, distingue 11 medidas clasificadas en 4 Administrativas, 4 Operativas y Técnicas

y 3 mediante Técnicas Específicas. Por otra parte, la información recogida en las Memorias de Sostenibilidad para este capítulo de contaminación acústica aporta una importante novedad: el registro de quejas y/o denuncias presentadas por los grupos de interés. Se contabilizan mediante el indicador A19 (número de quejas o denuncias sobre contaminación acústica llevadas a cabo por los stakeholders). Teniendo en cuenta que para este indicador se admiten 11 posibilidades de respuesta, la matriz de datos creada con la información de este indicador es de similares características a la generada para el anterior, es decir con 1.848 datos por año.

Igualmente, en esta parte de la investigación se utiliza el indicador A20, que describe la situación de los puertos en relación a los mapas de ruidos y planes de acción acústica. Por su carácter informativo y su especial implicación en las relaciones puerto – ciudad, resulta de especial interés tenerlo en consideración en el análisis llevado a cabo. Por último, como sucedía con el caso de la contaminación atmosférica, la investigación profundiza en las particularidades de los puertos según su tamaño, definido este en función de las toneladas de mercancías movidas anualmente.

Todo el valioso sistema de información propiciado por esta apuesta por la sostenibilidad y concretado en la explotación de las Memorias, conjuntamente con un desarrollo metodológico adecuado, dio lugar a las investigaciones que componen el núcleo de las Tesis Doctoral, conformado por las tres publicaciones que se aportan.

En la primera de ellas, *"Sustainability at Spanish ports specializing in liquid bulk: evolution in times of crisis (2010 - 2015)"* [Maritime Policy & Management (2019). Vol. 46 Nº 4, 491-507] se parte de una muestra de 6 puertos españoles que cuentan con refinería de petróleo en sus instalaciones. El singular grado de especialización de dichos puertos por tipo de tráficos resulta un caso idóneo para estudiar la evolución de sus niveles de sostenibilidad y, más especialmente, en períodos de crisis. El análisis

realizado se basa en la definición, creación y aplicación de un Índice Sintético Multidimensional para el período comprendido entre 2010 y 2015. Los resultados alcanzados permiten llevar a cabo un diagnóstico de la evolución de la sostenibilidad portuaria en dos aspectos relevantes: en primer lugar, globalmente, medida a través de las dimensiones económicas, institucionales, medioambientales y sociales de la sostenibilidad; y, en segundo término, por medio del análisis del comportamiento que ha seguido cada puerto en esta materia. Las conclusiones más específicas serían, entre otras, el hecho constatado de que los puertos con refinería de petróleo en sus recintos, a lo largo del periodo 2010-2015, han mantenido sus niveles de concentración en lo que se refiere al tráfico de refino de graneles líquidos, con un elevado nivel estabilidad en sus actividades. Sin embargo, esta especialización no lleva a una situación similar en cuanto a las posiciones que ocupa cada Autoridad Portuaria sus índices de desarrollo sostenible. De una parte, las dimensiones que evolucionan de manera más homogénea entre ambos años son, en primer lugar, la medioambiental en donde cuatro puertos mantienen en posición similar, de igual manera que en la dimensión social. En las otras dos dimensiones, económica e institucional, la evolución temporal no sigue pautas tan claras desde la perspectiva del desarrollo sostenible. Espacialmente, se distinguen claramente dos subgrupos dentro del conjunto de los puertos analizados: en términos globales, Bilbao, Cartagena y Tarragona mejoran sustancialmente en 2015 respecto a 2010; mientras que Algeciras, Castellón y Huelva se encontraban en una posición relativamente mejor en 2010. Debe destacarse que la metodología aplicada y la elaboración de índices de sostenibilidad desagregados por dimensiones, indicadores y subindicadores, permite discernir claramente las razones por las cuales cada puerto ha seguido pautas de comportamiento distintas en esta materia. En efecto, la observación y análisis de los valores tipificados de los indicadores permiten averiguar

cuáles han cambiado y en qué sentido lo han hecho. Todas estas circunstancias apuntan al hecho de que los avances en la investigación sobre sostenibilidad portuaria que vienen propiciados por la nueva normativa española, podrían y deberían desarrollarse en los restantes países europeos. En concreto, los resultados de esta aportación sugieren que esta acción debería incorporarse en las políticas europeas de gestión ambiental de los puertos, con criterios armonizados e indicadores homogeneizados. Esta política propiciaría el benchmarking entre puertos, así como instrumento para controlar las acciones gubernamentales y de las Autoridades Portuarias en materias de sostenibilidad, fomentando el desarrollo correspondiente de la legislación portuaria.

La segunda de las aportaciones "*Assessment of the tools to monitor air pollution in the Spanish ports system"* [Air Quality, Atmosphere & Health (2019) Vol. 12, 651 – 659] parte del hecho (como la tercera de las publicaciones presentadas) de que los puertos españoles se ubican, en su mayoría, en zonas urbanas o muy próximas a los entornos urbanos, por lo que sus actividades inciden de forma muy directa en la población. Por lo tanto, la reducción de la contaminación ambiental y en este caso concreto, la mejora de la calidad del aire, resulta un objetivo prioritario para la gestión de las Autoridades Portuarias en su apuesta por la sostenibilidad. La investigación estudia, mediante un análisis estadístico, la evolución y la eficacia de la implantación de 20 medidas para la reducción de la contaminación atmosférica en los puertos españoles. De igual forma, identifica las estrategias de gestión ambiental llevadas a la práctica: administrativas, operativas y técnicas y, por último, técnicas específicas. Se ha podido determinar que, a lo largo de la serie temporal estudiada, los puertos han basado su estrategia en la lucha contra la contaminación atmosférica en la implantación progresiva de medidas operativas y técnicas, administrativas y técnicas específicas que se han ido se ha ido incrementando paulatinamente a lo largo del período estudiado. Del análisis de cada

una de las medidas y su grado de implementación se concluye que las dotaciones y ordenación de infraestructuras e instalaciones especiales en los puertos resultan prioritarias, seguidas de acciones de supervisión y control. Destacan singularmente los aspectos normativos y regulatorias en las estrategias administrativas y, por último, la escasa presencia de incentivos a medios de transporte menos contaminantes.

Por último, la tercera de las publicaciones aportadas "*Port sustainability in Spain: the case of noise"* [Environment, Development and Sustainability (2019, DOI: https://doi.org/10.1007/s10668-019-00560-9] continúa en la línea emprendida en el artículo anterior. En este caso se parte igualmente de la hipótesis de que las actividades complejas que se realizan en los puertos producen fuertes impactos medioambientales. Entre ellos uno de los que más recientemente se han incorporado a las preocupaciones sociales e institucionales es la emisión de ruidos, con el consiguiente riesgo para el ecosistema natural y para la salud humana. La investigación comprendida en esta aportación se centra en el estudio de dicha problemática para los puertos españoles desde dos perspectivas: desde una visión institucional, estableciendo un diagnóstico de las causas de la contaminación acústica y las estrategias de prevención, intervención y control durante el período 2011 – 2016 y, en segundo término, comparando dicha perspectiva de las propias Autoridades Portuarias con el desempeño ambiental percibido e informado por parte de los stakeholders. Como resultados más sobresalientes de esta aportación destacar que se revelan como mayores fuentes de contaminación acústica en los puertos españoles el tráfico de camiones, el ruido procedente de la maquinaria portuaria y el de los buques atracados. Dichas causas pueden hacerse extensivas a cualquiera de los puertos, independientemente de su tamaño. En lo que se refiere a las estrategias adoptadas, existe un predominio de las actuaciones operativas y técnicas sobre las restantes categorías. No obstante,

atendiendo al tamaño de los puertos se produce una doble situación: los puertos pequeños y medianos optan por medidas operativas y técnicas; y los grandes usan más la vertiente administrativa y técnicas específicas. Una lectura exhaustiva de todas las medidas implantadas apunta más hacia la gestión y prevención que a la inversión en infraestructuras y con una orientación transversal, que permite centrar el foco de actuación en varias actividades generadoras de ruido. Por último, resulta especialmente interesante contraponer la percepción de los stakeholders con la posición de las Autoridades Portuarias en esta materia ya que los grupos de interés muestran su preocupación por dos procedencias bien diferenciadas: los locales de ocio (denunciadas por los vecinos y especialmente en puertos pequeños) y los buques atracados.

A lo largo de la Tesis se desgranan los aspectos más relevantes en el debate de la sostenibilidad portuaria y una serie de conclusiones que, si acaso, podrían sistematizarse desde varias perspectivas. De una parte, hay que referirse una vez más al hito que supone la promulgación de la Ley de Puertos en el año 2010 (Ley de Puertos del Estado y de la Marina Mercante, 2011) por su carácter avanzado, innovador e integral en materia de desarrollo sostenible, ya que significa establecer un compromiso normativo de los puertos españoles con la sostenibilidad. En particular:

a) La inclusión de la obligación de elaborar una Memoria de Sostenibilidad por parte de las Autoridades Portuarias dentro de los Planes de Empresa que deben presentar anualmente supone una novedad incuestionable. La revisión bibliográfica y el análisis de experiencias en esta materia en todos los ámbitos, llevada a cabo en la presente investigación, conducen a la conclusión que tal materia no se ha regulado de esta forma ni similar en ningún estamento e institución pública en España. Por otra parte, también se ha constatado que no

se da tal práctica normativa en los sistemas portuarios a nivel global (por ejemplo, en la UE). Existen, eso sí, actuaciones de naturaleza voluntaria, caso de asociaciones portuarias como la European Sea Ports Organisation (ESPO).

b) El desarrollo metodológico para la elaboración de las Memorias de Sostenibilidad obligatorias opta por la visión más adelantada del desarrollo sostenible: supera la versión tradicional de considerar exclusivamente la dimensión ambiental para incluir indicadores sociales, institucionales y económicos.

c) Otra cuestión destacable de dicha apuesta metodológica es sin duda el hecho de que se basa en elementos y experiencias anteriores, especialmente en actuaciones piloto de puertos y/o aportaciones de grupos de investigación especializados e instituciones y organismos creados para la propuesta de estándares de sostenibilidad. Las primeras aportaciones internacionales y europeas de los finales de los años 90 identificaban el desarrollo sostenible como un problema exclusivamente ambiental, ceñido a la capacidad institucional para gestionar los problemas típicos de los puertos: calidad del aire, ruidos y vertidos, entre otros. De igual manera el papel participativo de los stakeholders se consideraba completamente residual o nulo.

d) Una derivación muy importante de la información verificada y contenida en las Memorias de Sostenibilidad es que, al formar parte de los Planes de Empresa de las Autoridades Portuarias, se traduce en un elemento fundamental de gestión y gobernanza de los puertos desde la perspectiva de la sostenibilidad. Más si cabe si se tienen en cuenta los principios de obligatoriedad de rendición de cuentas y de transparencia que preside el tratamiento de esta información.

e) Por otro lado, la explotación de series temporales suficientemente amplias de los datos aportados por las Memorias, resulta una fuente de información que, correctamente tratada con metodologías adecuadas, abre perspectivas de futuro para nuevas investigaciones novedosas en este ámbito, como es el caso de las aportaciones que conforman la presente Tesis Doctoral.

f) Por último, se constata y propone una extensión de los avances llevados a cabo en España con esta normativa. De esta forma, una apuesta europea por acciones similares en el ámbito comunitario resultaría un elemento primordial para dotarse de herramientas y normas para una gobernanza común en materia de sostenibilidad portuaria.

1. Introduction

This Doctoral Thesis, *Sustainability in the Spanish port system; a quantitative approach,* adopts the *compendium of research articles* format, set out in Article 41 of the Regulations for Doctoral Studies of the University of Santiago de Compostela passed by the Governing Board of June 12 2017 and published in the DOG (Galician Official Gazette) No, 143 of 28 July 2017. Accordingly, it consists of three contributions, published in journals indexed in the SCI (Science Citation Index) or SSCI (Social Science Citation Index). They are all included in the Journal Citation Report (JCR) and, simultaneously, in the Scimago Journal Rank (SJR/Scopus).

Cohesion, thematic consistency and methodology

There are several points that highlight the cohesion, thematic consistency and methodology of the study. Among them:

1. Firstly, it stems from a *common, unique and original source of information,* drawn up ad hoc for the study carried out and embodied in the three publications. Since 2010, the Spanish Port Authorities that manage the 48 ports of general interest are legally bound to submit annual Sustainability Reports. Through the data in said reports and in the information provided by Puertos del Estado, the public body that coordinates and controls them, a database has been created on the 111 sustainability indicators of each and every one of the 28 Port Authorities that make up the state-owned system. The time series of the subject matter spans the period from 2009 to 2016, year of the most recent publication. Ultimately, a database has been created on the 24,864 starting positions, to which it is necessary to add those cases where the indicators have multiple answers, which highlights the scope and consequent complexity of the process. Therefore, a single database has been

generated to carry out the study that prompted the three contributions, as the matrices needed to analyse all the publications submitted have been obtained from this common source. The result of the data processing determines the next stage of the creation of sustainability indices and the application of specific techniques for the analysis of their behaviour.

2. Secondly, besides drawing from a sole source of original information, the three contributions are based *on the same subject matter*: Spanish ports of general interest and, on the other hand, on an identical topic: port sustainability.
3. Finally, regarding methodological aspects, Molina Serrano et al. (2017) highlight that:

> … "the application of the concept of port sustainability encounters *a shortage of methodology to evaluate the impact of the actions of the authorities* and companies in each of these four dimensions, determining the value and variables that *quantify their true contribution towards sustainable development*".

Following these principles, the dissertation aims to contribute some *methodological innovations*:

- In the first of these contributions, a methodology designed to that effect is applied, entailing the construction of a synthetic sustainability index for its application in port sustainability. A benchmarking study was carried out between Spanish ports of a specific specialisation (in this case, those with oil refineries in their facilities and, consequently, with high percentages of transport of crude oil and derivatives) and during a specific period (2010–2015), comparing progress in every sustainability development dimension from a comprehensive approach.
- The contribution made with the previous approach, which compares different sustainability paths taken by the ports, had a very significant outcome: during

the period analysed, the most stable dimension for the ports studied was the environmental one. Based on the same source of information, such an indication would open the door to analyse the reasons behind such behaviour in greater depth. Taking into account the range of indicators which make up said dimension, two specific aspects were selected that, in recent years, have been the main concerns of the European ports: air pollution and noise pollution (ESPO, 2018). Added to that is the fact that, for the most part, Spanish ports are located in urban settings, which influences port-city relationships and gives special importance to the phenomena relative to the influence in air quality and noise generation caused by port activities.

The operation of these two contributions draws from the premise of the database generated, in this case from the one corresponding to the 35 indicators of environmental performance of the Port Authorities, selecting the ones concerning all the pollution sources to be examined. Through a customised statistical analysis, the pollution sources, the measures adopted and their efficacy, and the perspectives of future actions to encourage sustainability in such areas have been extensively studied. In this case, aspects as decisive as the segmentation of the different ports by size and, most notably, the role of the stakeholders in the management of such topics have been taken into account.

Ultimately, there is a common denominator in the research procedure carried out. In addition, in each contribution the aspects of said methodology specific to each of them have been expanded and developed.

2. Goals

The *general goals* of the study are the following:

1. Carry out an empirical analysis of sustainability in the Spanish port system. All from a managerial approach both by Puertos del Estado, and individually for each of the Port Authorities.
2. Determine if the application of the environmental stipulations contained in the Ports Law have had a positive impact on the control and development of strategies for the reduction of contaminating emissions in the Spanish ports of general interest.

And the *specific goals* are as follows:

1. From the sustainable development perspective, determine the changes that have taken place in the Spanish Port Authorities with facilities specialising in the importation and refining of crude oil between 2010 and 2015, coinciding with the global economic crisis, and examine the paths said ports have followed from a sustainability perspective, understanding this within its comprehensive, multidimensional concept.
2. Determine if the application of the environmental stipulations contained in the Ports Law have had a positive impact on the reduction of contaminating emissions in the Spanish ports of general interest, analyse the development of the control measures and identify priorities.
3. Identify the noise sources produced in the ports and determine the strategies and actions followed to mitigate noise pollution.
4. Determine the influence of port size in the problems associated with port sustainability.

5. Analyse the stakeholders' perception of environmental performance of the Port Authorities and their influence in decision making.

3. Methodology

Regardless of the methodological aspects common to all the aforementioned contributions and the characteristics included in each publication, the dissertation is based on the information concerning the 111 indicators contained in the Sustainability Reports drawn up by the Spanish Port Authorities and classified according to the four dimensions of sustainable development.

The methodology of Laxe et al. has been followed for the drafting of the *synthetic sustainability index in the case of ports*, set out in the first publication (2016, 2017). The selection of variables for the period studied (2010-2015) responds to the need to rely on homogeneous data that enables the *port performance to be analysed from a multidimensional perspective*. There were substantial differences between the data-reporting methodology in the Sustainability Reports of 2010 with regard to subsequent ones, as they differentiated between two types of indicators: optional and priority. It is for this reason that in the Port Authorities as a whole, and more specifically in the chosen subgroup, (ports specialising in liquid bulk cargo), only six out of the eight included in the sample have complete and consistent data to conduct research. Accordingly, from the database generated, 48 perfectly equivalent, homogeneous variables were obtained and selected. These variables were grouped according to the four sustainable development dimensions (economic, institutional, social and environmental), classified into 11 indicators and 22 sub-indicators.

To research the last two contributions, which analyse the *port performance from an environmental perspective*, the first step was selecting the indicators representing two of the most relevant port management issues: air quality and noise: The structure of these indicators for 2011-2016 is consolidated and homogeneous.

The first of these contributions, in this case, the one referring to *air pollution***,** was based on the information from indicator A7 (air quality), defined as:

> A.7. Synthetic description of the measures implemented by the Port Authorities to control emissions linked to the activity of the port as a whole, whether they are administrative, operational or technical measures, such as the drafting of environmental standards, control of environmental operations by the port surveillance services, measurement of environmental parameters, restrictions on the handling of powdered cargo, or other initiatives.

This indicator allows for 20 different responses, made up of three possible alternatives: Eight administrative measures, six operational and technical measures, and six actions with specific techniques. With this information, a 20 x 28 response matrix was constructed for each year reported, allowing a total of 3,360 responses to be processed, recoded and statistically prioritised.

In addition to the global analysis, customised research was conducted, segmenting the results by port size, based on the most relevant classification criteria (ESPO, 2018; Puig el al., 2017).

The next priority in environmental sustainability analysed in the dissertation is the one concerning *noise pollution* in Spanish ports of general interest. The information contained in the Sustainability Reports regarding noise indicators is broader and more complex, requiring the use of several information matrices as described below, following the order carried out in the study.

The first of the indicators used (A18) is defined as:

> A18. Synthetic description of the main sources of noise present in the port or ports and which are relevant.

This indicator supports the identification of ten possible sources of noise pollution with five incidence levels. Therefore, a matrix of 10 x 28 values (and five subcategories) was prepared for every year of the 2011-2016 series.

Indicator A21 provides the following information:

> A21. Number of actions, and characteristics of said actions, undertaken during the current year on identified noise sources, as a result of the complaints and non-conformities registered by the Port Authorities.

Similarly, to the contents reflected in the air-quality indicator, 11 measures classified into four administrative, four operational and technical and three specific techniques are identified. Therefore, from the database it is possible to extract a matrix of 11 x 28 values for every year considered.

On the other hand, the information gathered in the Sustainability Report for this noise pollution chapter offers a significant development: the register of complaints and/or reports submitted by interest groups. They are accounted for using indicator A19:

> A19. Number of complaints or reports made by port interest groups (port community, urban areas, authorities, etc.) concerning noise emissions from port activity registered by the Port Authorities over the year. Availability of a systematised complaint management system.

Taking into account that 11 possible answers are allowed for this indicator, the data matrix created with the information from this indicator has similar characteristics to that generated for the previous one; that is, with 1,848 data per year.

Finally, an indicator (A20) is used, defined as:

> A20. Description of the situation of the Port regarding the noise map and noise action plan.

Due to its informative nature and its special involvement in port-city relations, it is very important to take it into account in the study.

Finally, as in the case of air pollution, the study explores the characteristics of the ports according to their size, defined in terms of the tonnes of cargo transported annually.

4. Results of the study

In Spain, ports of general interest are important centres of economic activity and, therefore, affect multiple interest groups. The importance they have for the urban centres where they are generally located and the environmental impact they generate is indisputable. And, therefore, the relatively recent inclusion of this sector in the field of public policies to promote sustainable development is significant.

The whole valuable information system facilitated by this commitment to sustainability and specified in the reports, together with an adequate methodological development, gave rise to the studies that make up the core of the dissertation, consisting of the three publications provided.

1. In the first one, *"Sustainability at Spanish ports specializing in liquid bulk: evolution in times of crisis (2010 - 2015)"* [Published in the Maritime Policy & Management magazine (2019). Vol. 46 No. 4, 491-507, DOI: https://doi.org/10.1080/03088839.2019.1569766] draws from of a sample of six Spanish ports with oil refineries in their facilities. Due to the type of traffic, the unique degree of specialisation of these ports makes them ideal cases for studying the evolution of their levels of sustainability and, even more, in periods of crisis. The analysis carried out is based on the definition, creation and application of a Multidimensional Synthetic Index for the period between 2010 and 2015. The results achieved allow a diagnosis to be made of the evolution of port sustainability in two relevant aspects: first, globally, measured through the economic, institutional, environmental and social dimensions of sustainability; and, secondly, by analysing the behaviour followed by each port shown in this area. More specific conclusions are, among others, the fact that the ports with oil refineries in their facilities,

throughout the 2010-2015 period, have maintained their concentration levels regarding the traffic of liquid bulk cargo for refining with a high level of stability in their activities. However, this specialisation does not lead to a similar situation regarding the positions that each Port Authority occupies in their sustainable development indices. On the one hand, the dimensions that have evolved more consistently in both years are, first of all, the environmental one, where four ports maintain a similar position, and the social dimension. In the other two dimensions, economic and institutional, there is no such clear pattern for time evolution from a sustainable development perspective. Spatially, two subgroups are clearly identified within all the ports analysed: in global terms, Bilbao, Cartagena and Tarragona improved substantially in 2015 compared to 2010, while Algeciras, Castellón and Huelva were in a relatively better position in 2010. It should be noted that the methodology applied and the development of sustainability indices disaggregated by dimensions, indicators and sub-indicators allow us to clearly see the reasons why each port has followed different behaviour guidelines in this area. Indeed, the observation and analysis of the typified values of the indicators enable us to find out which ones have changed and in what sense they have.

2. The second of the contributions *"Assessment of the tools to monitor air pollution in the Spanish ports system"* (Published in the Air Quality, Atmosphere & Health magazine (2019) Vol. 12, 651 – 659, DOI: https://doi.org/10.1007/s11869-019-00684-x) works on the assumption that (as the third of the publications presented) Spanish ports are located, for the most part, in urban areas or very close to urban environments, so their activities have a very direct impact on the population. Therefore, the reduction of

environmental pollution and, in this specific case, the improvement of air quality, is the main goal of Port Authorities in the management of their commitment to sustainability. The research studies, through a statistical analysis, the evolution and effectiveness of the implementation of 20 measures to reduce air pollution in Spanish ports. Likewise, it identifies the environmental management strategies put into practice: administrative, operational and technical, and, finally, specific technical strategies. It has been possible to determine that, throughout the time series studied, the ports have based their strategy on the fight against air pollution on the progressive implementation of operational and technical, administrative and specific technical measures that have increased gradually throughout the period studied. From the analysis of each of the measures and their degree of implementation, it is concluded that the provision and management of infrastructure and special facilities in ports are a priority, followed by supervisory and control actions. The legal and regulatory aspects of administrative strategies, and, lastly, the low presence of incentives for less polluting means of transport stand out in particular.

3. Finally, the third of the publications contributed *"Port sustainability in Spain: the case of noise"* (Published in the Environment, Development and Sustainability magazine (2019, DOI: https://doi.org/10.1007/s10668-019-00560-9) continues along the lines of the previous article. In this case, it is also based on the hypothesis that the complex activities carried out in the ports have important environmental impacts. Among them, one that has most recently become a social and institutional concern is noise emission, with the subsequent risk to the natural ecosystem and human health. The research included in this contribution focuses on the study of this problem area for Spanish ports from

two perspectives: from an institutional perspective, establishing a diagnosis of the causes of noise pollution and the prevention, intervention and control strategies during the period 2011 – 2016; and, secondly, by comparing the Port Authorities' perspective with the environmental performance perceived and reported by the stakeholders. The most significant results of this contribution are that truck traffic, noise from port machinery and docked ships are major sources of noise pollution in Spanish ports. These causes can be extended to any of the ports, regardless of their size. Regarding the strategies adopted, there is a predominance of operational and technical actions over the other categories. However, considering the size of the ports, a twofold situation occurs: small and medium-sized ports opt for operational and technical measures, while large ones use more administrative and specific technical measures. An exhaustive reading of all the measures implemented points more towards management and prevention than investment in infrastructures and with a cross-sectional direction, which enables the action to be focused on various noise-generating activities. Lastly, it is especially interesting to contrast the perception of the stakeholders with the position of the Port Authorities in this area, as the former show their concern for two very different sources: leisure facilities (reported by local residents and especially in small ports) and docked ships.

5. Discussion

Some features of the Spanish port system for ports of general interest

Dependent on the State Ports public body, the Spanish port system for ports of general interest consists of 46 ports, integrated and managed by 28 Port Authorities. An idea of its importance in the Spanish economy is given by the fact that, in 2018, it had a turnover of 1,157 million euros and a consolidated profit of 307 million. Freight traffic reached 563.5 million tonnes, transported over an available service area covering more than 10,200 hectares. That year, 46 million passengers and more than 174,000 merchant and passenger ships were recorded (Puertos del Estado, 2019).

The distinctive characteristics, among others, of these ports are the following:

- Location, amounting to four seaboards: Cantabrian, Atlantic, Mediterranean and islands.
- Size, depending on the number of tonnes transported and/or surface area.
- Degree of specialisation, according to the type of prevailing traffic or the existence of specific facilities that promote said traffic.
- Location, according to urban, suburban or out-of-city sites.
- Integration into global chains that define interconnectivity.

The management system for ports of general interest in Spain follows the Advanced Land Lord model. In this organisational model, the Port Authorities do not provide commercial or port services, which are carried out by private operators with their own human and technical resources. This way, the role of the Port Authorities is based on providing space and infrastructure to said operators and regulating their activity. The main goal is, therefore, to promote public-private collaboration in investment matters and to develop the regulatory aspects that facilitate such cooperation in order to attract

private initiatives to ports and, consequently, increase traffic and improve profitability. (Puertos del Estado, 2014).

The Spanish port system and sustainable development

The 1980s saw the emergence of a new *paradigm*, the concern for sustainability, and a new *development style*, one that is long-lasting and compatible with the principles of respect for the environment and interspatial and intergenerational solidarity (Jiménez Herrero, 2017, 126). Like all paradigm shifts, it does not come from isolated actions, but it is the result of a previous scientific background, as the relationships between the economy and the use of natural resources and the environment are not new (Van den Bergh, 1997, 11 et seq.). This new *idea-strength* is reflected in the publication of the Brundtland Report, sponsored by the World Commission on Environment and Development (WCED), 1987). This proposal has undoubtedly been a milestone in the development of the concept of economic growth regarding its relationship with the preservation of environmental assets. Not exempt from initial dialectical confrontations, these new sustainable development theories have been incorporated into the agendas of governments and institutions. For Jiménez Herrero (2017, 127-128), this conceptual agreement has been reached through the following arguments:

- Acknowledgement that ecological phenomena must be dealt with together with social ones.
- Launch of a new era of global cooperation that goes beyond the traditional approach of sharing natural resources, but also debates the exploitation of shared assets and waste absorption.

- Rekindling the idea of economic growth with *qualitative nuances*, in the sense of promoting an increase in the standard of living of the poorest citizens and countries, keeping the steady-state at bay.

Subsequently, the initial concept of sustainability, based on its exclusive relationship with natural resources, is redefined and replaced by a broader one that seeks the integration of the economic, social and environmental objectives of society in order to optimise the well-being of people without compromising that of future generations (Brundtland, 2002). The subsequent introduction of governance in the implementation of sustainable development implies acknowledging the role of institutions in this area, both to carry out these goals and to contribute to promoting social integration, gender equality, justice and, above all, encouraging participation (Spangenberg, 2007).

Ports are no strangers to this phenomenon and, at the end of the last century and in all spatial scopes (worldwide, European and most especially in Spain), a series of initiatives aimed at applying and promoting the principles of sustainability in port systems started to be developed (Bermúdez et al., 2019). The first actions took into account almost exclusively the environmental dimension to adopt, in more recent stages, more comprehensive methodologies.

In Spain, both the port system as a whole and some individual Port Authorities did not remain indifferent to the challenge of sustainability (Puertos del Estado, 2008, 7). Thus, 2010 witnessed an important milestone in the Spanish port system: the passing of the new Port Law (Law 33/2010) with a strong commitment to sustainable development. Specifically, in its consolidated text (State Ports and Merchant Navy Law, 2011), a clear commitment to port sustainability was adopted.

In particular, in Chapter I of Title III of the Law the planning lines for the ports are established. They are the following:

a) Strategic Plan

b) Infrastructure Master Plan

c) Port Authority Business Plan

With regard to the Business Plans, Article 55 of the consolidated text of the Law includes the creation of a series of sustainability goals and indicators for ports. Specifically, it states that:

> 1. The Business Plan will be prepared annually by the Port Authorities, in accordance with the goals defined, where appropriate, in the multi-year planning instruments that must comply with the government's economic policy. Said plan must contain at least the following: a situation diagnosis, port traffic forecasts, economic-financial forecasts, management goals, *the environmental sustainability goals and indicators of the port*, personnel structure and job supply, evolution of the management ratios, financial programming, public investment programming, estimation of private investments, annual profitability goals, corrective coefficients of the corresponding rates according to the conditions expressed in Articles 163 to 168 of the present law and the tax subsidies, if applicable, in accordance with the provisions of this law.
> 2. Public investment programming will include tangible, intangible and financial investments that have an annuity in the year referred to in the Business Plan or in the period associated with the multi-year action plan considered, with the corresponding distribution of annuities required by the project.
> 3. The corresponding economic-financial profitability studies and, where appropriate, the environmental impact assessment, must be carried out in those actions included in the programming of public investments that are relevant, following the criteria established in current legislation and in the guidelines established by Puertos del Estado.
> 4. The Business Plan will be accompanied by a *Sustainability Report that will be carried out in accordance with the methodology that will be approved, along with the environmental sustainability indicators, by Puertos del Estado, following a hearing with the Port Authorities.*

With this mandate, Puertos del Estado is developing a specific methodology to carry out the Sustainability Reports within the Port Authorities. It has adopted the multidimensional version of sustainable development based on the following principles (Puertos del Estado, 2014):

- *Economic sustainability*: in order to achieve medium- and long-term economic viability within a framework of contribution to the economic and social development of the environment, in which short-term management does not compromise future economic viability.
- *Environmental sustainability*: to protect the natural capital, optimising the management of natural resources within a framework of their renewal.
- *Social sustainability*: to contribute to the economic and human development of people within a framework of respect for their integrity and the participation of society as a whole.
- *Institutional sustainability*: to follow transparent, representative and objective government schemes, in an environment that guarantees the harmonious and balanced development of the previous dimensions.

Said methodology is based, initially, on the Global Report Initiative (GRI, 2009) standard, to later be expanded and completed in the Sustainability Reports.

Some relevant considerations stem from the above: the Spanish port system for ports of general interest is the only case in the EU where, due to legal regulations, the *idea-strength* sustainability model is adopted, regulating specific duties for Port Authorities in environmental management. This is an innovative and uniquely important action—there are no comparable regulations in Spain for similar state agencies and companies—which provides these organisations with a planning tool for the analysis, diagnosis and promotion of sustainable development. First, for the Port Authorities, as it enables them to ensure that their management is sustainable and to evaluate their results from this perspective, establishing any modifications necessary, as well as promoting the orderly planning of their actions following these principles. And, secondly, for Puertos del Estado, by allowing a comparative evaluation of the

aforementioned management of the different ports, in order to define best practices and, consequently, adhere to the global commitment to sustainability (Molina Serrano et al., 2017).

In this context, the dissertation is framed within the analysis of the performance of Spanish ports and their commitment to sustainability from two perspectives: the first one from a multidimensional point of view, through a contribution entailing the application of a synthetic sustainability index for a defined category of ports (in this case those specialised in liquid-bulk-cargo traffic and processing). And, secondly, from a port environmental performance standpoint, through two contributions regarding the institutional government and management of two characteristic port issues: air and noise pollution, introducing for this last case an institutional component, analysing the role of the stakeholders in the port governance in this area.

6. Conclusions

Throughout the dissertation, the most relevant aspects of the debate on port sustainability and a series of conclusions that, if anything, could be systematised from various perspectives, have been unravelled. On the one hand, it is necessary to refer to the milestone that is the enactment of the Law of Ports in 2010 (State Ports and Merchant Navy Law, 2011) for its advanced, innovative and comprehensive character in the area of sustainable development, as it means establishing a regulatory commitment of the Spanish ports with sustainability. Specifically:

a) The inclusion of the Port Authorities' duty to prepare a Sustainability Report within the Business Plans they must submit annually is an indisputable innovation. The bibliographic review and the analysis of experiences in this matter in all areas, carried out in this research, lead to the conclusion that such matter has not been regulated in this way or similarly in any public entities or authorities in Spain. On the other hand, it has also been determined that there are no such regulatory practices in port systems globally (for example, in the EU). There are, of course, voluntary actions, as is the case of port associations such as ESPO.

b) The methodological development for the drafting of the mandatory Sustainability Reports opts for the most advanced vision of sustainable development: it goes beyond the traditional version of exclusively considering the environmental dimension to include social, institutional and economic indicators.

c) Another notable issue of this methodological commitment is undoubtedly the fact that it is based on previous elements and experiences, especially on pilot actions by ports and/or contributions from specialised research groups and

institutions and organisations created for the proposal of sustainability standards. The first international and European contributions from the late 1990s identified sustainable development as an exclusively environmental problem, limited to the institutional capacity to manage the typical problems of ports: air quality, noise and spills, among others. Similarly, the participatory role of stakeholders was considered completely residual or null. One of the notable actions aiming to overcome this traditional approach is the MESOSPORT project (2007), the first significant experience in the Spanish port system that assimilated the precepts of Agenda 21, as well as the need to have a system of performance indicators under the conceptual filter of three-dimensional sustainability. It did not refer to the institutional dimension as a concept to be integrated into global sustainability, but it enabled ports to approach the content and philosophy of the GRI, which is more entrepreneurial in nature and thought of as a type-approval document rather than a benchmark or planning instrument. This tool proved to be pioneering, but insufficient when it came to designing the current Sustainability Report indicators, which subsume and extend the GRI methodology and, likewise, the one sponsored by MESOSPORT.

d) A very important branch of the information verified and contained in the Sustainability Reports is that, by being part of the Business Plans of the Port Authorities, it becomes a fundamental element of port management and governance from a sustainability perspective. Even more so if the principles of mandatory accountability and transparency that govern the processing of this information are taken into account. Despite the differences among the Spanish ports, the common result is that all of them have achieved a more sustainable

performance, what seems to point to the improvements of Spanish governance regarding this issue. The advances made in Spain should be complemented in the other European countries and the criteria should be harmonized, and the indicators homogenized. The conclusions of the investigation suggest to the European environmental management policy should incorporate this action.

e) Finally, the use of sufficiently large time series of the data provided by the Reports is a source of information that, correctly processed with adequate methodologies, opens up future prospects for new innovative research in this field, as is the case of the contributions that make up this dissertation.

Finally, I would like to note that, as can be observed in all the contributions carried out; their conclusions are *in line with proposed goals***,** both general and specific.

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ARTICLE 1 Sustainability at Spanish ports specializing in liquid bulk: evolution in times of crisis (2010 - 2015)

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Sustainability at Spanish ports specializing in liquid bulk: evolution in times of crisis (2010 - 2015)

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Abstract

In Spain, 28 Port Authorities of general interest moved more than 168 thousand tonnes of liquid bulk (34% of overall traffic) in 2015. Almost 82% of this amount corresponded to eight ports (G-8) that have a refinery within their facilities. This unique degree of specialization and concentration makes this set of ports an ideal sample to analyse the evolution of their sustainability levels, particularly during the crisis started in 2008 and onwards.

A proprietary methodology based on Multidimensional Synthetic Indices has been used. The comparison of the findings obtained for 2010 and 2015 allows a diagnosis of the evolution of port sustainability measured through the economic, institutional, environmental and social dimensions to be established, as well as a study of the patterns of behaviour that each port has followed in this issue.

Keywords: Crisis, sustainable development, synthetic indicators, ports, Spain.

JEL classification: H12**;** Q01; Q28; Q56.

1. Introduction

With globalization, the importance of maritime transport has grown very significantly, and ports have become an essential element of global production and supply chains. Not only has international maritime trade increased in recent years; ships have also improved their cargo capacity and ports have been forced to have larger and more efficient facilities and conditions of loading, storage and intermodality.

The new circumstances arising from the international financial crisis have contributed to the implementation at different ports of various strategies at various levels: with governments and public administrations, with clients and logistics companies and, lastly, with cities. Hence, in addition to generating impacts on economic activities, a port also generates significant impacts on local ecosystems.

Progressive port upgrades and adaptations are linked to greater environmental awareness. To the extent that significant environmental impacts can be caused (both in the ocean, land and in the air), environmental management techniques have been introduced. Also, port management now includes criteria for environmental protection and environmental performance of ports.

At present, such port management is determined by four factors. First, through the extension of the port's role in the industrial and logistic chains. Secondly, because of changes in the structure of vertical integration (through connection and linkage with other maritime or intermodal service providers, such as rail transport companies) and horizontal integration (mergers or cooperation between businesses of different ports). Third, through the new redefinition of the role of hinterlands and forelands. And, finally, through the new commitments and strategies of port clients. These new scenarios, emerging from the 2007 crisis, introduce three clear evolutions: port-

devolution and decentralization processes as a reason for the port reforms undertaken; processes of greater private participation coupled with restrictive labour policies; and changes in the port-selection criteria and factors, which have an influence on the routes and on the hierarchy of ports at a worldwide and regional level.

1.1. Background

This new dynamic of the port system has led to this being studied from different approaches. In this regard, Bichou and Gray (2005) analysed the port system from three overviews: macro-analytical (including the ports' relationships with public policies, including actions that drive the growth of the port and its environmental perspective); micro-analytics (analysing internal issues as well as relationships with cargo and passenger transfers and their integration into the logistics chains); and a hybrid one (combining elements from the previous sections as well as the role and functions of the port). Elsewhere, Paixao and Marlow (2003) classified ports into four generations, taking into account the terrestrial/maritime transport interface, the provision of services and consolidation of loads, those linked to the production and logistics chains and, finally, the use of just-in-time and lean production techniques in terms of management. Nowadays recent research speaks in the meantime of the fifth and sixth generation ports (Lee and Lam, 2015, Lee et al, 2018, Kaliszewski, 2018).

The performance analysis has also been a constant over the last few years. Talley (2006a) defined it as a function of economic and technical productivity, both of which are complementary concepts. Bichou (2006) warned of corporate taxonomy and stakeholder perception, given the complexity of the system and the dissimilarities between functional strategies and business strategies. Yueng, Zhang and Cheung (2013) established both absolute and trend indicators to determine the highest levels

of efficiency. For their part, Talley, Ng and Marsillac (2014) encourage an analysis of performance both from a global perspective and from the levels of each internal service provider, such as operators, regulatory bodies or the companies themselves; in particular, they identified the performance for each area of the port. Kiztmann and Asmus (2006) explained that port environmental management arises from the need to provide political and institutional responses to environmental problems and to the potentially significant problems for the ports.

Sutomo and Soemardjito (2012) divided the indicators into two major groups: effectiveness (using physical measurements) and efficiency (those linked to port costs). To which Talley (2006b) would have stated that a port is more efficient when being more productive and competitive, by reducing the costs related to the transport times of its clients. Finally, Brooks (2006) emphasized four criteria of efficiency: prices, time of the process, availability and reliability, for which internal indicators (featuring financial and non-financial ones) and external indicators (those relevant for clients, suppliers and stakeholders) are required.

Environmental performance indicators are beginning to be used as awareness raises through the application of sustainable development. First, it is a question of analysing economic development with respect to the environmental development. In this way, tools (such as ISO 14000 standards) and management systems (such as EMAS) were created. Later, indicators and variables that could simplify and, simultaneously, provide information on the state of a complex system, such as the port, are put forward.

Henri and Journeault (2008) considered five functions of environmental indicators: helping to be an auxiliary tool in communication; ensuring the conformity of environmental processes; assisting in the process of formulating procedures; seeking

to decentralize information systems; and contributing to knowledge and dissemination. Asgari et al. (2015) linked port environmental management indicators to value chain sustainability, as did the studies by Denktas-Sagar and Karatas-Cetin (2012). For their part, Yap and Lam (2013) tried to reconcile port developments with sustainability policies, in the same way as the works of Acciaro et al. (2014). The studies of Hiranandani (2014) and Kuznetsov et al. (2015) emphasize holistic approaches to port sustainability policies and highlight the relevance of stakeholder participation in the definition of objectives for the determination of the instruments of an action focused on environmental port performance.

Peris-Mora et al. (2005) had already submitted contributions on the consideration and evaluation of environmental performance indicators for the port of Valencia. As well, Saengsupavanich et al. (2009) had analysed the environmental indicators of private ports in Thailand according to environmental standards. Lirn, Wu and Chen (2013) investigated the main environmental performance indicators of the ports of China, Hong Kong and Taiwan, presenting a multi-criteria analysis using the AHP (Analytic Hierarchy Process) method. For their part, Puig, Wooldridge and Darbra (2014) developed a method to identify and select environmental indicators called Environmental Performance Indicators (EPI). Silva (2014) contributed, for Brazilian ports, relevant considerations regarding the economic effects of the use of environmental performance criteria. Shiau and Chuang (2015) developed a port sustainability indicators system with three dimensions and 34 indicators for Keelung port. Seguí et al. (2016) developed certain criteria for the European Federation of Inland Ports (EFIP) and Lu, Shang and Lin (2016), using a structural equations model, studied the effects of sustainable management on the supply chain. They used data from a survey conducted with 135 persons at the ports of Keelung, Taichung and

Kaosiung. Subsequently, González-Laxe et al. (2016, 2017) tested a Synthetic Indicator, made up of 64 and 56 variables respectively, that allows the four dimensions of sustainable development in Spanish ports to be identified. More recently, Puig et al. (2017) developed an indicator guide for European ports within the PPRISM programme, combining ISO-14001, EMAS and PERS standards. Lastly, Chen and Lam (2018) proposed a data envelopment analysis (DEA) to measure sustainability in a quantitative way and they applied it to 20 ports in Europe, Asia and America, specialised in containers.

From the institutional perspective, ESPO (2012a) divides ports into three sections: potential areas (including storage, transportation and administration); the port/ship interface; and the maritime area. Following this outline, the possibilities of establishing indicators are linked to these functions. As regards the former, dredging, soil contamination, management of noise, waste, water resources, emissions and air quality, monitoring, reporting and contingency plans are included. For the second function, the management of ships' waste, cargo movements and hazardous cargoes would be grouped together. And, for the third one, maritime safety and emissions from ships would be included.

Likewise, through the PPRISM project, ESPO highlights five main indicators divided into the following topics: trends and market structures; socio-economic indicators; environmental indicators; logistics chains and operational efficiencies; and governance indicators (ESPO, 2012b).

Until now, the port environmental management indicators came from surveys carried out with the Port Authorities and agents of the maritime-port community (ESPO, 2017). The proposal of this research, based on the elaboration of a port sustainability

index, allows the comparison of different realities under the same variables and facilitates comparability for different time periods. Likewise, the synthetic index helps avoid the introduction of subjective elements in the analysis. It also increase the reliability of the results by encompassing indicators from the four economic, institutional, social and environmental dimensions (Doerr, 2011).

1.2. Situation of the Spanish port system.

Spain is the EU country with the longest coastline and more than 96% of its frontiers are maritime. The port sector represents 2.07% of GDP and generates around 100,000 direct jobs (in addition to 60,000 indirect and 116,000 induced jobs), accounting for 1.23% of the country's total employment.

In terms of aggregate data, Spain holds first place in containers (16%) and fourth position in bulk traffic (12%) in the EU-28 (González and Collado, 2012). Three Spanish ports are among the world's top 100 in terms of containers and among the top twenty in Europe.

The Spanish port system comprises 28 state-owned Port Authorities (PA), denominated of general interest, that manage 46 ports, in addition to others for which the regional authorities are responsible. The system of organisation and management of ports for which *Puertos del Estado* is responsible has the characteristics of the French or landlord model (Barnes-Dabban, Van Koppen and Mol, 2017).

In 2015, ports moved 488 million tonnes, of which 54% is bulk traffic (34.4% liquids and 19.6% solids). The rest corresponds to general cargo, of which 70.97% are containerized goods (Puertos del Estado, 2015). Over the 2010-2015 period, liquid bulk loses just one percentage point (from 35.64% to 34.41%), dry bulk increases almost one percentage point (from 18.83% to 19.65%) and general goods only increase

their share of total traffic by half a percentage point (from 45.53% to 45.94%). Accordingly, in terms of traffic composition, the 2010-2015 period is fairly stable (Puertos del Estado, 2010; 2015).

Analysing the distribution of liquid bulk traffic, it can be seen that two different patterns are followed. The first of these is that there is a remarkable concentration dynamic. The weight of the eight ports (G-8) that have an oil refinery within their confines is increasing. It reached 81.85% of the total liquid bulk of the Spanish port system in 2015, a figure very similar to that posted five years earlier (Table 1). Moreover, of particular note is the weight of the first five ports (Algeciras, Bilbao, Cartagena, Huelva and Tarragona), which jointly account for 68.54% of Spanish traffic in these products. The second issue to be highlighted is the increase in liquid bulk traffic in the port confines of Huelva, Algeciras, Tarragona and Cartagena, compared to the decreases recorded in A Coruña, Bilbao, Castellón and Santa Cruz de Tenerife.

In the same way, port specialization and, with this, the conditionality of traffic can be analysed, given the existence of specialized installations within the port confines. In 2015, there were 6 Port Authorities where liquid bulk accounted for more than 50% of their total traffic. Depending on this specialization, three subgroups can be characterized. In the first of these, there is a strong concentration of liquid bulk traffic, such as Huelva (79.36% of its traffic), Cartagena (79.01%) and Tarragona (67.72%). The second subgroup would include A Coruña (57.94%), Bilbao (56.17%) and Castellón (52.62%). And finally, the third subgroup of just two ports of the G-8 registers percentages of their liquid bulks below 50% of the total traffic of their respective port. They are Santa Cruz de Tenerife (47.60%) and Algeciras (29.73%), although the latter is the port with the highest volume of liquid bulk traffic in Spain.

These dynamics of specialization seems to be reinforced over the 2010-2015 period. At the ports of Cartagena, Huelva and Tarragona, over the last five years the weight of liquid bulk has increased in relation to total traffic. And, contrariwise, this percentage decreases at the remaining ports.

Table 1. Evolution and participation of liquid bulk in Spanish ports with oil refinery within their confines.

Port	Liquid bulk (tonnes)		% Liquid Bulk/Total Spain		% Liquid Bulk/Total Port	
	2010	2015	2010	2015	2010	2015
A Coruña	8,533,758	7,913,588	5.88	4.71	63.87	57.94
Bay of Algeciras	19,483,549	27,344,044	13.43	16.27	36.12	29.73
Bilbao	19,684,508	18,199,807	13.57	10.83	58.71	56.17
Cartagena	20,847,754	25,741,107	14.37	15.32	78.96	79.01
Castellón	8,949,177	8,654,177	6.17	5.15	61.6	52.62
Huelva	12,927,243	21,598,676	8.91	12.85	76.26	79.36
S.C. Tenerife	9,558,027	5,732,686	6.59	3.41	55.47	47.6
Tarragona	18,646,119	22,306,303	12.86	13.27	59.79	67.72
G-8	118,630,135	137,490,388	81.80	81.85		
Spain	145,029,181	168,051,085	100	100		

Source: own elaboration based on Puertos del Estado (2010, 2015)

2. Research objectives

The research is part of the task of evaluating the legal framework related to port sustainability with regard to the behaviour and trajectory of its indicators, in order to verify the improvement of the environmental management model and facilitate the interpretation of those dynamics.

This work has focused on the ports that have petroleum refineries in their premises. The authors keep with the logic that these Port Authorities and their managers should have a higher level of sensitivity to environmental problems, given the theoretical risks involved in having such facilities in its enclosures.

Fig.1. The G-8 ports in Spain

In addition, in the Spanish case, there are two very relevant phenomena: the first is related to the total traffic volumes of said ports because they are highly conditioned to the presence of those facilities. This traffic represents more than half of all the goods moved. And the second is that this is captive traffic, with some homogeneity in the distribution of loads, which facilitates comparability.

On the other hand, these two aspects must be interpreted bearing in mind that the geographical distribution of this type of port is very close to the economic spaces to which the refined end product is supplied (two ports on the Atlantic face, one on the islands' space, and five in the Mediterranean area). It is within this specific context that this research is framed, and its objective, as well as the selection of certain specific ports, is understood.

Therefore, it is a question of examining the different paths followed by the PAs that have oil refineries within their confines[1], and of assessing the different dimensions of sustainability in their integral and multidimensional concept, represented by economic, institutional, environmental and social aspects.

The interest of the work lies in the analysis and trajectory of the sustainability indicators for those Spanish ports in which oil refineries are located. These indicators reflect the "integral nature" of the set of parameters that affect sustainability, giving the opportunity to evaluate a port as a whole and not a specific traffic. The research results make possible the compatibility between socio-environmental sustainability and economic rationality, as defined in the Spanish port legislation itself. It therefore allows us to contextualize both a new vision of sustainable development in the port area with the requirements of greater transparency and disclosure of results.

To do this, a static-comparative analysis is carried out between two moments: in 2010 (in the midst of the economic crisis) and in 2015 (where the Spanish economy seems to be coming out of the recession). The aim is therefore to verify the changes that have taken place at Spanish ports specializing in the import and refining of oil over the period mentioned and from the perspective of sustainable development.

3. Origin of data and the variables considered.

The values of the variables for 2010 and 2015 have been provided by Puertos del Estado.

[1] At the ports of A Coruña, Bilbao, Cartagena and Tarragona the oil refinery is managed by Repsol. At the ports of Bay of Algeciras, Huelva and Santa Cruz de Tenerife the management company is CEPSA. Lastly, British Petroleum manages the refinery at the port of Castellón.

However, this process has two aspects that need to be considered to provide the variable values with a verifiable quality and, consequently, to guarantee the reliability of the research findings.

First, the methodology developed by Puertos del Estado for the compilation of the Reports was subject to certain variations and was fine-tuned from the outset. Accordingly, there are some differences between the calculation method and the number of variables completed between 2010 and 2015. Once the data is debugged, a total of 48 variables can be considered perfectly equivalent and homogeneous. In accordance with the methodology used, the latter are classified in a pyramidal way into the aforementioned 4 dimensions and, in turn, into 11 indicators and 22 sub-indicators[2]. The summary of this selection process is included in Table 2 and the description of the sub-indicators and variables in the appendix.

Second, there are two Port Authorities that have several problems in collecting the data of the variables. These are the ports of Santa Cruz de Tenerife and A Coruña[3]. The lack of data or the doubts about the quality and reliability of the values for the initially considered variables suggest that these PAs should be excluded from the analysis. Both represent only 9.41% of the liquid bulk traffic of the Spanish port system. Therefore, from this moment onwards, the research is confined to the remaining ports, decreasing

[2] The considered variables are similar to those verified and tested in previous research of the authors (González Laxe et al., 2016, 2017), referenced in this paper, with the particularity that, in this case, they apply to ports that specialize in liquid bulk.

[3] This PA either offers incomplete data or does not provide information on its Sustainability Reports.

the group from 8 to 6 (G-6), which represent 73.66% of the total of this traffic in Spain, a sufficiently significant percentage.

4. Methodology

Once a methodology has been designed, which has already been applied to study relationships between economic and environmental indicators for a wide sample of Spanish ports (González Laxe et al. 2016), this approach was extended to the four well-known dimensions of sustainability to develop and calculate a Port Sustainability Synthetic Index. This would allow the comprehensive analysis from the perspective of the sustainable development of the ports (González Laxe et al. 2017).

This research aims to take a further step in extending the use of the aforementioned methodology when applying the same bases[4] introducing two variants: first, the scope of study is restricted exclusively to the Spanish ports previously analysed, specifically those with significant liquid bulk traffic (G-8); second, calculations are performed for two different time periods (2010 and 2015), which will allow to establish the static-comparative analysis guidelines fixed in the terms previously indicated in the objectives.

To verify that the percentiles calculated for the four dimensions are representative of a normal distribution condition, the Shapiro-Wilk test[5] is applied (using the SPSS statistical program), obtaining a level of significance in all cases greater than 0.05.

[4] In order not to be repetitive, details of the procedure can be found in González Laxe et al. (2017), more specifically section 3, Calculation Methodology.

[5] This type of test is used because it is a distribution with a small number of variables.

This verifies that the null hypothesis has been checked and the values follow a normal distribution.

Table 2. Classification of variables selected by dimensions, indicators and subindicators.

DIMENSION	INDICATORS	SUBINDICATORS	VARIABLES
Economic	Economic structure	3	9
	Business and servicing	2	4
Institutional	Institutional capacity	2	7
	Protection of human and natural capital	2	2
Environmental	Environmental management	2	5
	Ecoeficiency	3	4
	Environmental quality	2	5
Social	Social capital	1	2
	Human capital	1	2
	Fairness	2	4
	Health	2	4

Source: own elaboration.

5. Results

Once the entire calculation system has been carried out according to the proposed methodology, the results achieved are presented in three stages. First, the values typified by indicators are shown in Table 3. Second, in Table 4, the z - scores of each sustainability component are presented for each port.

Finally, based on the weighting of the typified values of each sub-indicator and through their conversion into standard normal percentiles, the position of each PA is obtained within the range of 0 - 100, per dimension and for each year (Table 5).

5.1. Discussion: evolution of the sustainability at Spanish ports specializing in liquid bulk (2010 - 2015)

For the set of ports that have the specific characteristics of being intensive in the traffic of liquid bulk and which have an oil refinery located within their confines, the analyses of sustainability are approached according to the methodology used. It is carried out

Table 3. Values of indicators (z - scores or typified) by ports and dimensions (2010 - 2015)

			Bay of Algeciras	Bilbao	Cartagena	Castellón	Huelva	Tarragona
Economic	Economic structure	2010	0.4426	-0.4400	0.4038	-0.1445	-0.3620	0.1449
		2015	-0.3344	0.0983	0.7436	-0.3754	0.1224	-0.2545
	Business and servicing	2010	0.5000	-0.3600	-0.0835	-0.3234	-0.1585	0.4253
		2015	0.6338	-0.2536	-0.1864	-0.3258	-0.2679	0.4000
Institutional	Institutional capacity	2010	-0.1209	0.8171	-0.3869	-0.1703	-0.3316	0.0030
		2015	-0.2493	0.2704	0.6090	-0.4487	-0.7047	0.4293
	Protection of human and natural capital	2010	-0.1597	-0.5123	0.8945	1.7104	-0.5388	-0.5388
		2015	-0.8840	-0.6278	-0.7193	0.9263	0.6821	1.0858
Environmental	Environmental management	2010	-0.2272	1.2642	-0.1471	0.1205	-0.3390	-0.6714
		2015	-0.1003	0.2018	-0.8854	0.3224	0.3767	0.1601
	Eco-efficiency	2010	-0.5788	0.4106	-0.3173	0.0312	0.3199	0.1895
		2015	0.1265	0.2244	-0.7877	0.2792	-0.2452	0.4027
	Environmental quality	2010	0.7129	0.5348	-0.8568	-0.6261	0.0546	-0.3569
		2015	1.1224	1.1862	-0.6016	-0.8597	-0.4073	-0.2028
Social	Social capital	2010	0.8199	-0.3880	0.0339	-1.0465	0.9024	-0.3217
		2015	0.4395	0.0031	0.2801	-0.2250	-0.2255	-0.2721
	Human capital	2010	1.1589	-0.6022	0.0123	0.3712	-0.9403	0.0000
		2015	1.1268	0.5545	-0.2491	-0.1817	-1.6576	0.4070
	Fairness	2010	-0.3191	-0.8893	-0.0484	1.9563	-0.6982	-0.0017
		2015	-0.3500	0.3994	-0.4365	1.4185	-0.5915	-0.5730
	Health	2010	-1.0383	-0.7095	0.5781	0.4599	0.4345	0.0052
		2015	-1.1495	0.7298	-0.1907	1.3161	-0.6599	-0.0458

Source: own elaboration.

Table 4. Values of the z - scores by ports and dimensions (2010 - 2015)

	Economic		Institutional		Environmental		Social	
	2010	2015	2010	2015	2010	2015	2010	2015
Bay of Algeciras	0.4603	-0.0365	-0.1296	-0.3903	0.0081	0.4012	-0.1227	-0.2388
Bilbao	-0.4154	-0.0100	0.5217	0.0708	0.7598	0.5598	-0.6980	0.4693
Cartagena	0.2539	0.4574	-0.1022	0.3138	-0.4492	-0.7561	0.1843	-0.2039
Castellón	-0.1996	-0.3601	0.2477	-0.1431	-0.1716	-0.1121	0.6929	0.8437
Huelva	-0.2994	0.0023	-0.3777	-0.3965	-0.0102	-0.0810	-0.0942	-0.7310
Tarragona	0.2312	-0.0531	-0.1174	0.5752	-0.3131	0.0998	-0.0524	-0.1838

Source: own elaboration.

Table 5. Results by ports and dimensions (2010 – 2015)

		Economic	Institutional	Environmental	Social
Bay of Algeciras	2010	100.00	60.00	50.00	43.33
	2015	44.62	31.11	47.14	53.33
Bilbao	2010	0.00	86.67	92.86	14.17
	2015	53.85	55.56	74.29	76.67
Cartagena	2010	73.85	17.78	27.14	71.67
	2015	87.69	82.22	7.14	43.33
Castellón	2010	33.85	53.33	47.14	72.50
	2015	0.00	33.33	51.43	80.00
Huelva	2010	26.15	15.56	51.43	43.33
	2015	61.54	13.33	55.71	10.00
Tarragona	2010	66.15	62.22	31.43	46.67
	2015	52.31	84.44	64.29	36.67

Source: own elaboration.

both in accordance with the four dimensions adopted, and taking into account the particularities of the respective ports. Said analysis is employed to classify the hierarchy that interrelates the set of such ports with each other, as well as in a relative way.

On the other hand, studying the findings in depth requires a better display of these. Accordingly, the contents in Table 5 have been converted into radial graphs, both in terms of clustering into dimensions and for the specific analysis of each of the ports considered.

5.1.1. Results by dimensions

Figure 2 shows the sustainability diagrams for the four dimensions considered, which are then analysed in detail.

a) Economic

In 2010, in the midst of the economic crisis, Algeciras was the outright leader of this dimension, followed by Cartagena and Tarragona. The situation changes in 2015:

Cartagena comes to spearhead the economic dimension, with Huelva in second place. Tarragona remains third in the hierarchy.

All this takes place because of the different orientations and diversification of the traffic and the different positioning of the ports in accordance with the specialization. As shown above, both Cartagena and Huelva strengthen their position in liquid bulk, while Castellón (which worsens appreciably in 2015) focuses its traffic towards general goods.

b) Institutional

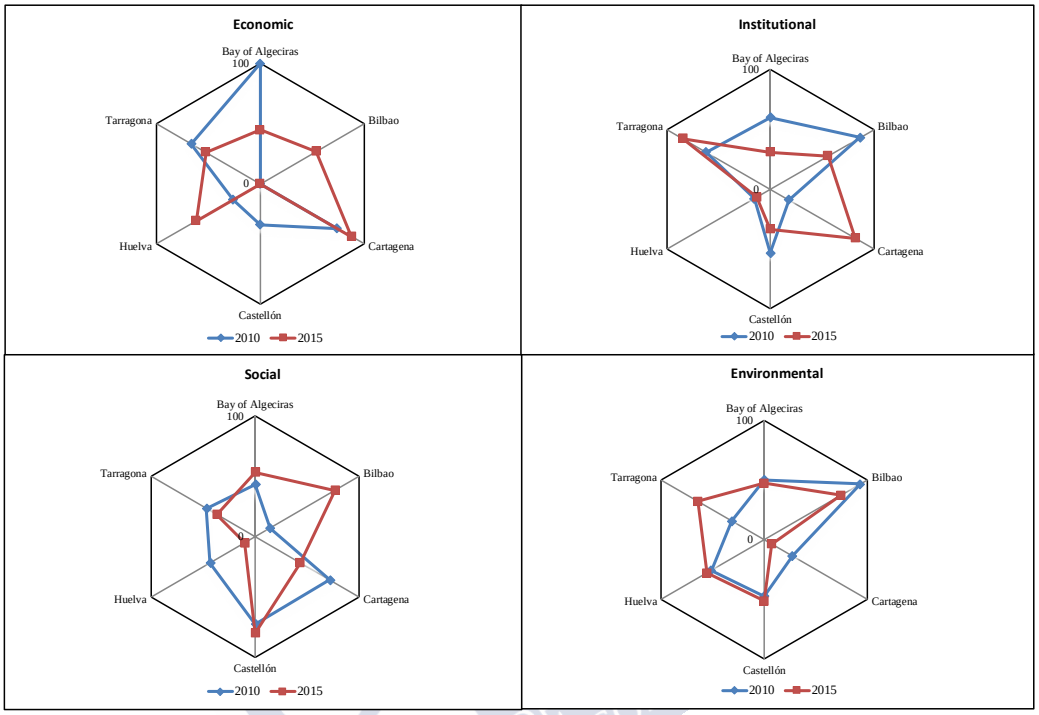
It is one of the areas in which substantive changes can be observed over the five-year period analysed. The notable improvements of Tarragona and Cartagena ports that are leading the indices in this dimension in 2015 are to be highlighted. Contrariwise, there are losses in the relative positions at the ports of Bilbao, Algeciras and Castellón, which in 2010 topped the ranking in the institutional dimension. The lowest relative level corresponds to Huelva port in both years. Overall, the improvements in their positions reflect a more intense action in this area at those ports where the share of liquid bulk has increased in the total of their traffic. And, on the contrary, the ports that have opted for a greater diversification of their merchandise have reduced their relative values in this dimension.

c) *Environmental*

This is without question the dimension that has remained the most stable over the period considered. Algeciras, Castellón and Huelva remain practically identical; which means that, in general terms, the commitment of each of these ports is maintained with this dimension. Bilbao moves backwards, but very slightly. And, finally, Tarragona and Cartagena offer divergent behaviours: the former gains positions, while the latter

worsens. Consequently, there is little variation in the hierarchies, which indicates certain stability in port policies with respect to the Port Authorities' environmental performance regarding the characteristics mentioned.

Fig. 2. Diagrams of sustainability by dimensions.



Source: own elaboration.

d) Social

In this sustainability dimension, Castellón has strengthened its leadership over the years and Bilbao and Algeciras have also improved their positions. In the other direction is Tarragona, with a slight decrease in the hierarchy, and in particular Huelva, which in 2015 ranked last. It could be said that, in general, there is no single behaviour and trend in this social dimension, with regard to the ports that have refineries within their confines. Contrariwise, as each port has broad autonomy in its decision-taking levels and as it depends on the needs of its customers, it acts under different criteria and actions.

5.1.2. Results by ports

The same as for the dimensions, to carry out the analysis of the results by Port Authorities, the sustainability diagrams for each of those that have been taken into account (Fig. 3) are shown.

a) Bay of Algeciras

In 2010, Algeciras was the port with very balanced indicators of sustainability between dimensions and hegemony in the economic (with the maximum possible value) and institutional aspects. In 2015, the environmental and social aspects remain virtually stable, but those in which it stood out have a weaker presence. Thus, it loses positions in the economic dimension (due to the worsening of its position in the indicator of Economic structure) and in the institutional one, favoured in this dimension by a lower value in the Human and Natural Capital Protection indicator. However, in general, this port represents a high balance in the four dimensions over the 2010-2015 period.

b) Bilbao

This Port Authority is practically contrary to Algeciras. In 2010, although the values it had in the institutional and environmental dimensions were the highest of all G-6 ports, those of the economic and social dimensions were quite the opposite, the worst. Nevertheless, the 2010-2015 period has shown a very remarkable tendency towards the commitment to social and economic indicators, correcting their low ratios of five years ago. In 2015, it has a greater balance between dimensions, despite a decrease in its indices comparing with the other ports in the environmental and institutional aspects.

c) Cartagena

In 2010, this port had a relatively prominent position in the economic and social dimensions and was fairly weak in the remaining two dimensions. Over the period elapsed, there is deterioration in both the social dimension (the indicators of Human Capital, Fairness and Health offer lower values) and the environmental one (low hierarchy in Environmental Management and in Eco-efficiency). On the contrary, in 2015 it is in a better position on the economic side that was already fairly extensive in 2010 but, above all, it boasts a very important qualitative leap in the institutional dimension, a consequence of the high value it achieves that year in the Institutional capacity indicator.

d) Castellón

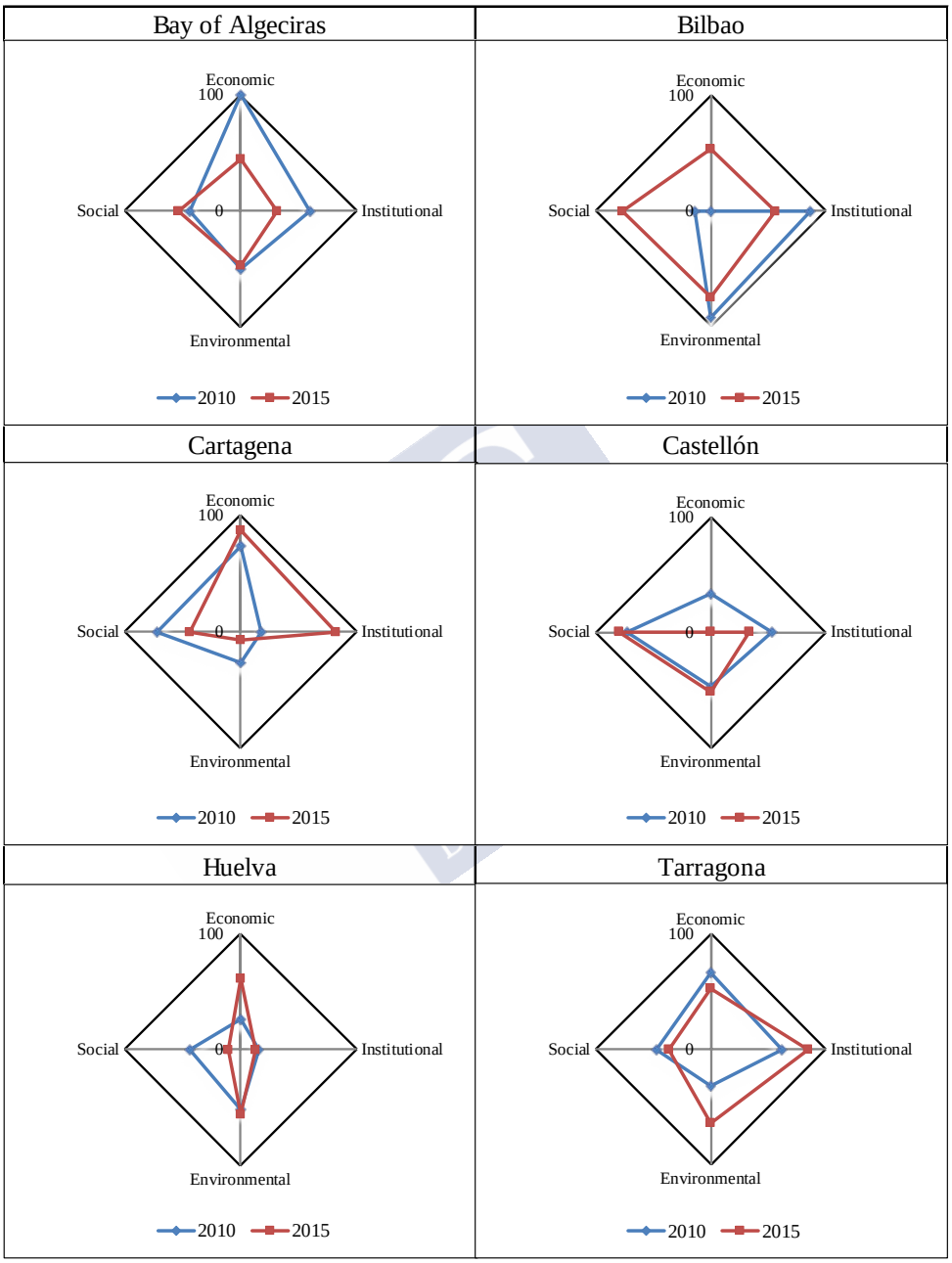
This Port Authority displays unbalanced behaviour, since in terms of social and environmental dimensions it remains practically in an average area of the G-6 during the 2010/2015 period and with very few significant increases. This behaviour is not similar in terms of the economic dimension, as the port of Castellón in 2015 occupies the last position. This is due to a special fall in the two indicators that make up this dimension (Business and services and Economic structure). The institutional part also worsens through the decline in the institutional capacity indicator.

e) Huelva

In its whole, this is the port that reveals the smallest hierarchy by dimensions. It starts from an average situation in the environmental and social fields in 2010; and very low in institutional and economic aspects. The latter two dimensions are similarly maintained in 2015 and in the others, there is a reverse effect; the improvement of the Economic structure indicator produces an upward effect on this dimension. Elsewhere,

the worsening of the Social Capital, Human Capital and Health indicators means that the social dimension posts the lowest value of all the ports analysed for 2015.

Fig. 3. Diagrams of sustainability by ports.



Source: own elaboration.

f) Tarragona

In 2010, this port started with a relatively balanced position in the dimensions analysed, except for the environmental aspect. In the last five years, it has regressed

very slightly in the economic and social dimensions, but it improves appreciably in the institutional and environmental dimensions, due to actions linked to these dimensions. Good evidence of this can be seen in the higher values of the indicators of Institutional capacity and Protection of human and natural capital, on the one hand, and Environmental management and Eco-efficiency, on the other.

6. Conclusions

The analysis of the indicators related to sustainable development is one of the main concerns of the Port Authorities, and they are beginning to be included in the institutional agendas of the same. The justifying reasons are given by the greater public and professional pressure that force new obligations to be included in the official regulations.

In addition, in their reports and in their annual reports the PAs want to show sustainability-related information to increase their commitment to transparency and seek to make known their actions in this area. Accordingly, these indicators help both to highlight their institutional commitments and to underline a new brand image of PAs. In particular, indicators represent ancillary tools of communication, encourage the enhancements of reputation and help to display greater levels of security.

Thus, the analysis of the indicators reflects a commitment to improve the challenges of the four dimensions of sustainability and to reveal new attitudes aimed at achieving better ratios compared to other rival ports.

In this regard, Spanish legislation is clear, because several examples about the obligation to include elements related to environmental requirements are put forward.

In this way, and as a summary, the Revised Text of the 2011 Ports Act requires: The Port Infrastructure Master Plan with an environmental report (Art. 54); in all concessions and authorizations awarded by PAs, the conditions for the protection of the port environment are specified (Art. 56); and it is mandatory to present an annual sustainability report (Art. 55).

The actions in port environmental performance must contemplate a regulation system together with the adoption of support technologies that allow both to promote and foster interrelations with the environment. Specific measures are needed to provide environmental management systems and codes to all ports as well as responsible practices, in order to increase the degree of awareness and collective responsibility.

On the other hand, the results of the research invite reflection: How have the Port Authorities behaved from the comprehensive perspective of sustainability? The data obtained allow a series of considerations to be highlighted.

First, during the 2010-2015 period, the ports with oil refineries within their confines have maintained their concentration levels with regard to the traffic of liquid bulk.

Second, some ports have substantially changed their levels of specialization by modifying, on the one hand, the participation of other traffic and, on the other hand, maintaining a high level of stability in their activities. Nevertheless, this specialization does not lead to a similar situation regarding the positions of each PA in its sustainable development indexes. Thus, the most homogeneous dimensions between both years are, first of all, the environmental one, where four PAs remain in a similar position, as well as in the Social dimension. In the other two dimensions, economic and institutional, the time evolution does not follow such clear patterns, which presupposes

certain instability on both sides and always from the perspective of sustainable development.

Third, two sub-groups are clearly distinguished within the G-6 ports as a whole. Overall, Bilbao, Cartagena and Tarragona improved substantially in 2015 compared to 2010, while Algeciras, Castellón and Huelva were in a relatively better position in 2010. In other words, each sub-group has different sustainability paths. Hence it can be affirmed that there is heterogeneity in the commitments and in the challenges.

In fourth place, the methodology applied, and the compilation of sustainability indices broken down by dimensions, indicators and sub-indicators, clearly distinguish the reasons for which each port has followed different behaviour patterns in this area. In fact, observing and analysing the typified values of indicators makes it possible to ascertain, without a doubt, which ones have changed and how. Therefore, it is not difficult to conclude that this opens the door to future lines of research from a more complete perspective: synthetic indicators of sustainability are important sources of information that bring to light aspects of the economy that remained hidden (Moffatt, 1996).

Accordingly, they are very important for decision-making, especially for the public policies of managing the Spanish port system under the principles of sustainable development and reveal the importance of introducing port sustainability indicators, an issue which for Shiau and Chan (2015) is particularly urgent.

However, it should be noted that there are no strong incentives to deepen the commitment to greater port sustainability. That is to say, the incentives have not yet been high enough to serve as a competitive, differentiating or generating element of port selection policies. And all this despite the fact that both the European institutional

agendas and the port strategies of the PAs include declarations and statements in this regard.

The current and significant efforts of the ESPO (2017) regarding the environmental priorities of the ports are limited, for the time being, to the voluntariness of the responses to the proposed surveys, which suggests replacing the analyses through surveys with quantitative methods (Lu, Shang and Lin, 2016).

Despite the differences among the Spanish ports, the common result is that all of them have achieved a more sustainable performance, what seems to point to the improvements of Spanish governance regarding this issue. The advances made in Spain should be complemented in the other European countries. The criteria should be harmonized, and the indicators homogenized. Our results suggest to the European environmental management policy should incorporate this action. Once this homogeneity is reached regarding variables and indicators of sustainable development in port organizations (either at national, European or international levels), this quantitative analysis results in a useful tool for benchmarking among ports. It is also applicable to control Governments' and Port Authorities' actions in matters of sustainability. Consequently, it also encourages the decision-making of environmental-economic policies, as well as the corresponding development of port legislation.

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Appendix: Description of the variables

Economic Dimension

INDICATOR	SUBINDICATOR	DESCRIPTION
ECONOMIC STRUCTURE	Value generated and productivity	Turnover per employee
		EBIDTA per employee
	Economic and financial situation	Return on assets
		EBIDTA by tones
		Debt servicing
		Operating costs/operating revenue
	Level and structure of investments	Public investment /Cash Flow
		Third-party investment/public investment
		Asset renewal rate
BUSINESS AND SERVICING	Business	Occupancy rate/Net turnover
		Activity rate/Net turnover
	Services	Tones per square meter service area
		Tones per meter active dock

Institutional Dimension

INDICATOR	SUBINDICATOR	DESCRIPTION
INSTITUTIONAL CAPACITY	R&D+i activities, port-city interface and promotion	Investment and expenses in R&D+i
		Investment and expenses in improving port-city interface
		Investment and expenses in trade promotion
	Infrastructure and services	Percentage of land area for commercial use, licensed
		Percentage of concession land used
		Use of railway
		Use of loading and unloading by Ro-Ro
PROTECTION OF HUMAN AND NATURAL CAPITAL	Risks for human capital	Economic resources used in protection and security
	Risks for natural capital	Economic resources used in environmental issues

Environmental Dimension

INDICATOR	SUBINDICATOR	DESCRIPTION
ENVIRONMENTAL MANAGEMENT	Economic Behavior of the PA in environmental issues	Costs associated to the introduction of an environmental management system
		Costs in environmental characterization and monitoring
		Costs in terrestrial cleaning
		Costs in cleaning the water surface
	Environmental training	Percentage of workers with environmental training
ECO-EFFICIENCY	Efficiency in ground use	Percentage of the terrestrial service area occupied on asset facilities
	Energy consumption	Percentage of electricity consumption by the service zone surface area
		Percentage of fuel consumption by the service zone surface area
	Water consumption	Percentage of water consumption by the service zone surface area
ENVIRONMENTAL QUALITY	Quality of interior waters	Percentage of terrestrial surface area that has rainfall collection network
		Percentage of service zone surface area that has rainfall collection network
	Wastewater treatment	Percentage of the terrestrial service zone that has a water treatment network (irrespective of where it discharges and the treatment received)
		Percentage of the terrestrial service zone that has a treatment network connected to the municipal collector or WWTP
		Percentage of surface area that discharges into septic tanks

Social Dimension

INDICATOR	SUBINDICATOR	DESCRIPTION
SOCIAL CAPITAL	Employment	Temporary workers over all full-time workers
		Percentage of employees covered by collective bargaining agreement
HUMAN CAPITAL	Training	Percentage of workers that follow training programs.
		Percentage of training hours per worker.
FAIRNESS	Gender equality	Percentage of women regarding all workers
		Percentage of women outside the agreement regarding all workers.
		Percentage of women outside the agreement regarding all workers outside the agreement
	Labour structure	Personnel renewal rate
HEALTH	Occupational accidents	Annual frequency of accidents index
		Annual severity of accidents index
		Annual absenteeism index
	Occupational health and safety	Training effort in prevention

ARTICLE 2 Assessment of the tools to monitor air pollution in the Spanish ports system.

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Assessment of the tools to monitor air pollution in the Spanish ports system

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Abstract

In general, seaports are located in urban areas or in their environs, whereby their activity has a very direct effect on the population. Therefore, reducing environmental contamination and improving air quality are priority management goals for port authorities (PAs).

In Spain, the state-owned seaport system consists of 28 PAs that manage 46 ports. Its regulation received a major impulse through the enactment of the Spanish Ports Law in 2010. The law establishes especially the obligation that, annually, the PA prepare a Sustainability Report with 111 sustainability indicators.

This study is founded on a database that was created with information from the Reports from 2011 to 2016. A statistical analysis studies the evolution of the implementation of 20 measures for the reduction of atmospheric contamination in Spanish ports and identify the strategic lines carried out by the PAs and the measures adopted depending on the size of the ports.

Keywords: Port management, environmental management, indicators, sustainability, legislation.

JEL classification: K32; Q01; Q28; Q53

1. Introduction

Seaports, both because of their location in urban areas or in their environs, and also because of their activity, are a source of environmental contamination that mainly affects air quality, a fact that has consequences on human health. This fact, among others, has impelled the adoption of concrete measures to minimise this impact, demanding a proper and adequate management of the sources of air pollution in port systems to mitigate harmful effects on health (Bailey and Salomon, 2004, Sorte et al., 2018).

Port systems have not remained on the sidelines of environmental awareness. This awareness began to acquire greater relevance in all areas as of the 1990s. The American Association of Ports Authorities (AAPA), the public ports alliance between the United States, Canada, the Caribbean and Latin America, were pioneers in the adoption of institutional measures, by proposing a series of recommendations regarding environmental issues for the groups of ports that belong to this association (AAPA, 1998). In Europe, several initiatives have also originated, such as the European Sea Ports Organisation (ESPO) in 1994, which published a first version of the Environmental Code of Practices, which was later revised in 2001 and 2003 (ESPO, 2012a). On the other hand, the ECOinformation Project (1997) set forth two very clear goals in matters of port environmental policy: identifying its main problems and subsequently categorizing them to later develop a port classification. By using a survey-based methodology and repeating the same survey over several years, the most significant environmental impacts were classified in a number of lists. Air quality was underlined as the main and fundamental goal within port management, resulting from the surveys and proposed strategies (Darbra et al., 2004, 2005).

In Spain, the most outstanding achievement in this regard is MESOSPORT (2007), led by the Port Authority of Valencia, and developed based on prior studies by Crespo Soler et al. (2007). It sets forth an approach to a methodology that served government Port Authorities to draft sustainability reports based on the three aspects of sustainable development (economic, social and environmental) following the guidelines of the Global Report Initiative (GRI, 2009). The result was reflected in a document titled *Guidelines for the drafting of sustainability reports in the Spanish port system* (Puertos del Estado, 2008). From then on, a number of Spanish ports voluntarily began to develop reports based on those principles.

2. The importance of controlling air quality in port systems

In order to abate the impact of air pollution on port activities, Gupta et al. (2005) emphasised the need to monitor and control these activities, an opinion that was later endorsed by Dinwoodie et al. (2011).

De Langen (2007) considers there is a common problem in all ports: port development leads to a conflict of interest with the protection of the environment, with the inhabitants that live near port areas and with the labour conditions of port workers. This is why the role of stakeholders is key in the environmental process. This is stated by Hall et al. (2013) who consider that mutual collaboration between these stakeholders and the Port Authority (PA) is essential for establishing and defining sustainable policies that respect the environment.

There is plenty of further literature that on the whole mainly favours the definition, identification and proposals for the selection of emission indicators in port matters. The ESPO, referring to the five indicators of the PPRISM project, introduces the category of environmental indicators for ports (ESPO, 2012b). Puig et al. (2014)

developed a method for identifying and selecting environmental indicators for ports, known as Environmental Performance Indicators. Accioro et al. (2014) pointed out the importance of having environmental performance indicators in ports, concluding that their implementation and use significantly reduces the sources of greenhouse gases. On the other hand, after analysing the priorities of 79 ports members of the ESPO, Puig et al. (2015) concluded that during the period 1996 - 2013, air quality was a residual issue that later became one of high priority.

Puente-Rodriguez et al. (2016) designed a fourfold proposal of port environmental indicators: water quality, energy use, noise and air quality; Antão et al. (2016) defined a proposal for a system of port performance indicators based on aspects involving occupational health and safety and the environment.

Recently, Puig et al. (2017a) developed a guide of environmental indicators applicable to all types of ports within the programme PPRISM and combined it with standards ISO-14001, EMAS and PERS. Similarly, Puig et al. (2017b), per initiative of the ESPO, carried out an analysis of a sample of ports that were evaluated using a self-diagnosis method (SDM). Their conclusion could not be more meaningful: all ports considered air quality to be their main priority in environmental matters. Lastly, evaluations on the impact of port activity on the air quality of the surrounding urban area have been carried out recently, both from a general perspective (Baldasano and Massagué, 2017) as well as from the perspective of the port's specific activity (Sorte et al., 2019).

3. Introduction to the principles of sustainable development in the Spanish port regulations

The European Union's recommendations on port policies[1] along with previous experiences adopted at their own initiative, is the basis for including the commitment to sustainability by Spanish PAs in the Law on State Ports and the Merchant Navy 33/2010.

This regulation, as it is worded in the revised text that appears in R.D. 2/2011 (Ley de Puertos del Estado y de la Marina Mercante, 2011) explicitly indicates (in the Article 55) the planning instruments to be used by the PAs, which include the obligation of annually drafting a business plan containing the port's environmental sustainability objectives and indicators, and that it be accompanied by a Sustainability Report whose methodology is to be approved by Puertos del Estado. This methodological approach is based on the development of its own and specific indicators, introducing the institutional dimension as well as the three previous ones included in the initial experimental project (Puertos del Estado, 2008)[2]. Specifically, the selection of indicators in the environmental dimension was based on the analysis by (Fernández Francos et al., 2013):

- What the pressures or impacts of port activities on the environment are.
- Actions that can be taken by the PAs to limit the impact of the port community as a whole.

Based on these principles, indicators were introduced that were connected to:

[1] See Document COM 616 (2007).

[2] The new methodology is based on the development of 111 indicators found in the four dimensions of sustainability. In this regard, the proposal represents the inclusion of 60 indicators more than the previous one, based on the more corporate prescriptions of the GRI.

- Environmental management and allocated economic resources
- Environmental quality
- Ecoefficiency
- Introduction of management systems in the port community

Based on this philosophy and as of the passing of the Law, each PA began the drafting of their Sustainability Reports as per the methodological principles developed by Puertos del Estado (Puerto de Barcelona, 2014).

4. Research objectives

Practically all of the revised bibliography regarding emissions by ports points to the absolute priority of adopting measures that guarantee air quality. However, it is not easy to find clear references to the specific measures that should be adopted or any evidence as to the extent to which they are applied.

The Sustainability Reports by the 28 Spanish PAs (that manage 46 state-owned ports of general interest) provide highly valuable information which, when conveniently drawn up, makes it possible to formulate the following objectives for this study:

a) Verify whether the implementation of the Ports Law has had a positive impact on promoting and setting up measures for controlling and reducing emissions at Spanish state-owned ports of general interest.
b) Determine if the level of implementation of tools for the control of emissions has evolved progressively.
c) Identify the specific measures adopted and under what category they have been included.
d) Analyse if there are substantial differences in the actions adopted in order to mitigate air pollution depending on the size of the ports.

e) Identify and typify the strategic lines carried out by the PAs and their correspondence with the measures adopted.

5. Methodology

In the mentioned document drafted by Puertos del Estado to produce the Sustainability Reports, of the 111 indicators it develops for ports, 35 fall within the environmental dimension (Puerto de Barcelona, 2014). Of these, the one identified as A7 provides information on the measures set forth by the PAs to control air quality and emissions resulting from port activity. Specifically, a set of measures (with their descriptors) are included, which are classified under three categories:

a) Administrative (8 items).

b) Operational and technical (6 items).

c) Specific technical (6 items).

Accordingly, all the PAs must respond to what degree they have implemented those 20 specific actions. The detailed classification of each measure for the above categories is shown in Table 1.

On the other hand, having indicated the aim of the mentioned actions for controlling and improving the quality of air in the seaport system, each category from the above table can be reclassified depending on the nature of each one, as shown in Table 2. We can see that the 20 proposed measures are based on strategic lines by the PAs through:

a) Direct supervision and control actions

b) Adoption of measures for the management of infrastructures and facilities

c) Regulation of operational and specific policies

d) Installation of special facilities.

a) Providing incentives to third parties for the use of systems that reduce the level of emissions.

Table 1. Air polluting emissions: statement of measures introduced by the Port Authorities (Indicator A7).

Administrative	Operational and technical	Specific technical
1. Mandatory regulations and disciplinary proceedings.	1. Monitoring port operator regulatory authorisations and notifications regarding emissions.	1. Installation of windbreaks.
2. Good practices guidelines and voluntary environmental codes.	2. Specific instructions from management for certain operations.	2. Irrigation systems for bulk storage and roads.
3. Systems to measure air quality parameters or regular campaigns.	3. Direct supervision at wharfs by Port Authority technicians.	3. Wheel wash systems.
4. Characterisation studies of the effect of port activities on air quality.	4. Reorganisation of port's plant activity to move sources of emissions away from sensitive areas.	4. Warning and information systems involving wind speed.
5. Incentives for lorries with lower contaminating emissions.	5. Interior road improvement to reduce lorry traffic through urban areas.	5. Operational shutdowns caused by adverse wind conditions.
6. Include conditions on emissions in the specifications that regulate services.	6. Environmental criteria in the organisation and allocation of berths.	6. Incentives for lorries with automatic load covers or installation of points for load covering
7. Demand requirements on emissions in conditions for the granting of concessions.		
8. Signing of good practices agreements.		

Source: Authors' own based on environmental indicator A7 (Puerto de Barcelona, 2014)

Table 2. Classification of measures and strategies for the control of emissions according to type and characteristics.

	Supervision and control	Infrastructures and equipment	Policies and regulations	Special facilities	Incentives
Operational and technical	3	3			
Administrative		1	5		2
Specific technical	1	1		3	1
Total	4	5	5	3	3

Source: Authors' own

Now that the Ports Law has become operative, verified results are already available for a sequence of 7 consecutive years (2010-2016). The sources of information used are for 2010 from the Sustainability Report for the system of ports of general interest (Puertos del Estado, 2012) and for the remaining years the information is provided directly by Puertos del Estado.

However, during the first year of operation (2010), the fulfilment of the items under indicator A7 was voluntary for the PAs; it did not become mandatory until 2011. Therefore, it was possible to create a homogenous and consolidated database for the six-year period of 2011-2016.

The operation for the calculation of these five years consisted of building a 20 x 28 matrix of values for each year, processing 3,360 responses or data for the entire period which was then used to analyse, among other aspects, the frequency of the measures adopted and their hierarchies.

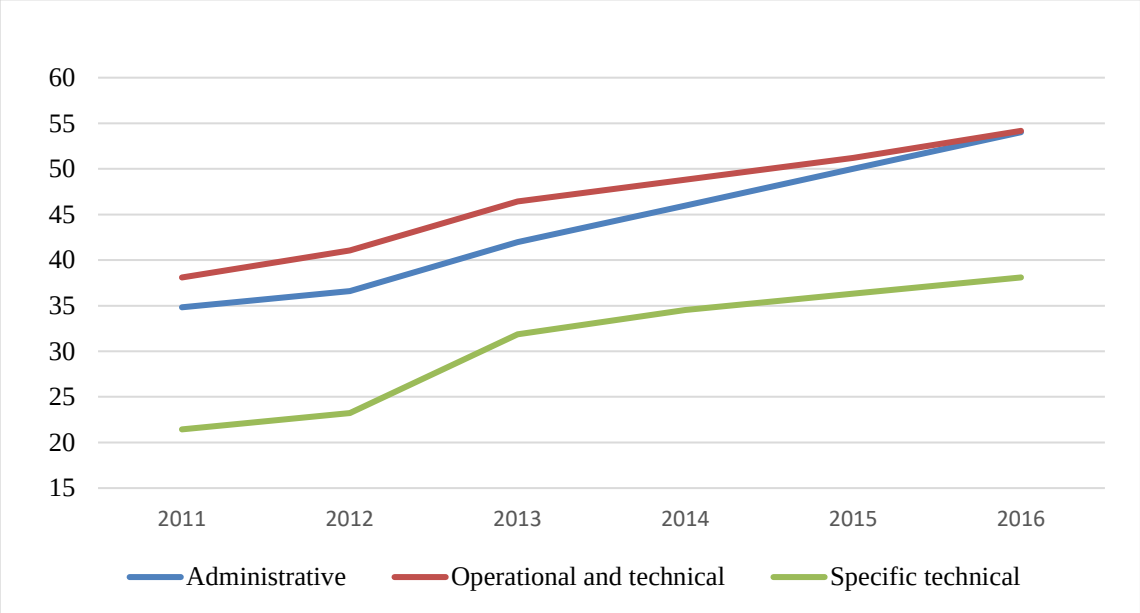
6. Findings

6.1. Global

Figure 1 shows the cumulative totals and their evolution during the period referred to. Several matters need to be highlighted: first of all, the Spanish PAs have given priority to the adoption of operational and technical measures to control emissions. Secondly,

they support administrative actions (that in 2016 reached the level of the first ones) and finally, they favour the application of specific techniques.

Figure 1. Evolution of the percentage of PAs that have implemented measures for controlling and reducing emissions (2011-2016)



Source: Authors' own.

Moreover, the upward trend in the measures introduced as the time frame progresses; that is, as the precepts of the Ports Law[3] are gradually applied, especially from 2012 to 2014, is a significant fact. This upward trend also reveals a feature worth highlighting: it happens almost simultaneously for each of the three categories considered[4]. In short, Spanish PAs choose to develop environmental management policies that are increasingly more comprehensive as the studied period progresses.

[3] This Act introduces quite novel aspects in environmental management, as is the case of the demand for means to prevent and reduce marine, atmospheric and land contamination in all manner of facilities that are located in ports (Art. 62.2), a strict sanctioning system (Art. 306.1.a) and the rescue of the concession in the event of environmentally harmful actions (Art 99).

[4] By processing the basic data used to create Figure 1, we get a Pearson correlation coefficient of 0.988 ($p = 0.000$) for the evolution of operational or technical and administrative measures; of 0.986 ($p =$

6.2. Results according to measures adopted

The use of the database makes it possible to determine the importance of the measures introduced by each PA to mitigate emissions within each category and, at the same time, by using an analysis of frequencies, to prioritise or establish the operational levels for each one. In this way, the findings are shown (for each strategy) classified from greater to lesser priority based on the higher frequency (level 1) of adoption of each measure. Likewise, they are analysed based on the order of priorities as stated by the ports.

6.2.1. Technical and operational measures

The findings for the first group are shown in Table 3.

The table shows that the 6 technical and operational measures have grown considerably during the period studied. It is important to highlight that the three measures of higher operational level result from direct PA actions on port operations through its technical staff (supervision of wharfs, operator control and specific instructions). The next three in rank refer to the use and management of port infrastructures (berth environmental criteria, reorganisation of plant activity and road improvement to reduce lorry traffic in urban areas).

6.2.2. Administrative measures

As was the case for the ones analysed in the previous section, with the exception of offering incentives for lorries with lower emissions (of limited presence), all these measures reveal an upward trend during the time span for the period studied (Table 4).

0.000) for operational or technical and specific technical measures, and of 0.965 (p = 0.003) for administrative and specific technical measures. All of the significance levels (p) are lower than 0.05.

The first four operational levels stand out, particularly the introduction of systems to measure air quality parameters and the organisation of regular campaigns. In 2016, 4 out of every 6 PAs had already implemented them. Equally, they had laid down good practices guidelines, carried out studies on the effect of port activities on air quality and established mandatory regulations and disciplinary proceedings. A quite similar behaviour is seen in the introduction and promotion of good practices agreements with the operators; an activity that has increased considerably by 240% since 2011.

Table 3. Hierarchy of technical and operational measures adopted by the PAs to reduce emissions and percentage of PAs that have introduced them (evolution of frequencies 2011 – 2016)

LEVEL	TECHNICAL AND OPERATIONAL MEASURES	2011	2012	2013	2014	2015	2016
1	Direct supervision of wharfs by Port Authority technicians.	53.57	53.57	67.86	67.86	71.43	71.43
2	Monitoring port operator regulatory authorisations and notifications regarding emissions.	42.86	42.86	50.00	57.14	60.71	64.29
3	Specific management instructions for certain operations.	32.14	35.71	35.71	42.86	46.43	53.57
4	Environmental criteria for berth management and allocation.	32.14	42.86	42.86	42.86	42.86	46.43
5	Reorganisation of port's plant activity to move sources of emissions away from sensitive areas.	32.14	32.14	42.86	42.86	46.43	46.43
6	Improvement of interior roads or accesses in order to reduce lorry traffic through urban areas.	35.71	39.29	39.29	39.29	39.29	46.43

Source: Authors' own

6.2.3. Specific technical measures

The behaviour of the PAs during this period for this type of measures is similar: as of 2011 the level of implementation grows, especially with regard to equipment for irrigation systems in bulk storage areas and roads. In general, these consist of special

equipment to prevent environmental contamination, and they are closely linked to the idiosyncrasies of each port and their degree of specialisation (Table 5).

Table 4. Hierarchy of the administrative measures adopted by the PAs to reduce contaminating emissions and percentage of PAs that have introduced them (evolution of frequencies 2011 – 2016)

LEVEL	ADMINISTRATIVE MEASURES	2011	2012	2013	2014	2015	2016
1	Systems to measure air quality parameters or regular campaigns.	53.57	60.71	60.71	64.29	64.29	64.29
2	Good practices guidelines and voluntary environmental codes.	42.86	46.43	57.14	57.14	64.29	64.29
3	Characterisation studies of the effect of port activities on air quality.	39.29	42.86	53.57	64.29	64.29	64.29
4	Mandatory regulations and disciplinary proceedings.	42.86	42.86	46.43	57.14	64.29	64.29
5	Demand requirements on emissions in conditions for the granting of concessions.	25.00	25.00	42.86	46.43	60.71	60.71
6	Signing of good practices agreements.	39.29	39.29	39.29	42.86	42.86	60.71
7	Include conditions on emissions in the specifications that regulate services.	32.14	32.14	32.14	32.14	35.71	50.00
8	Incentives for lorries with low levels of emissions.	3.57	3.57	3.57	3.57	3.57	3.57

Source: Authors' own

Table 5. Hierarchy of technical and operational measures adopted by the PAs to reduce emissions and percentage of PAs that have introduced them (evolution of frequencies 2011 – 2016)

LEVEL	SPECIFIC TECHNICAL MEASURES	2011	2012	2013	2014	2015	2016
1	Irrigation systems at bulk storage areas and roads.	35.71	35.71	53.57	53.57	60.71	64.29
2	Operational shutdowns caused by adverse wind conditions.	35.71	42.86	42.86	42.86	42.86	42.86
3	Wheel wash system	17.90	17.90	37.51	39.30	42.86	42.86
4	Warning and information systems involving wind speed.	21.43	21.43	32.14	35.71	35.71	39.29
5	Installation of windbreaks.	14.30	17.90	21.43	32.14	32.14	32.14
6	Incentives for lorries with automatic load covers or installation of points for load covering.	3.57	3.57	3.57	3.57	3.57	7.14

Source: Authors' own

6.3. Results based on port size

In its comparative analysis for ports environmental performance, Puig et al. (2017b) classified a sample of 91 European ports according to the volume of tonnes moved. They identified four subgroups:

- Small ports that move up to 5 million tonnes/year
- Medium ports, between 5 and 15 million tonnes/year
- Large, that move between 15 and 50 million tonnes/year.
- Very large, over 50 million tonnes/year.

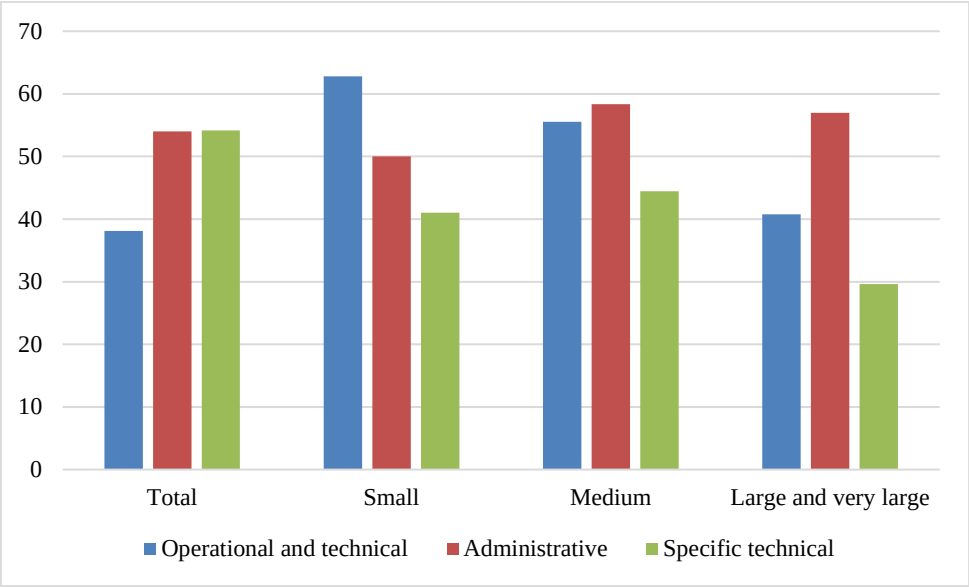
As they had already done for the total number of ports, they verified the specific environmental priorities for each category and concluded that in 2016, air quality always ranked first place.

Taking into account that 2016 was the last year of analysis carried out in this investigation and that the measures implemented are progressive, the 28 Spanish PAs can be classified by size according to the volume of tonnes moved in 2016, according to the same intervals. The data for traffic were those obtained from Puertos del Estado (2016). Accordingly, there are subgroups of PAs: small (13), medium (6) and large and very large (9). Based on this classification, each category can be analysed to determine if there is a differentiated behaviour in the adoption of control measures for air quality and the reduction of environmental contamination (Figure 2).

The results for the whole port system reveal that in 2016, 54% of the PAs had adopted both administrative and specific technical measures for controlling emissions. The figure for operational and technical measures was of 38%.

There follows an analysis of the distribution of these measures according to port size.

Figure 2. Percentage of PAs that have implemented measures for controlling and reducing emissions according to type of measure and port size (2016)



Source: Authors' own

6.3.1. Small ports

The 13 Spanish ports that moved less than 5 million tonnes in 2016 have specialised in the adoption of operational and technical measures. The only exception is direct supervision at wharfs by Port Authority technicians (which nevertheless have been adopted by 77% of the smaller PAs); in all the others they stand out above larger ports. From the administrative measures, it is worth highlighting those involving good practices guidelines and voluntary environmental codes, characterisation studies of the effect of port activities on air quality and mandatory regulations and disciplinary proceedings, adopted by 69% of small ports. Finally, from the specific technical measures, the one with the greatest impact has been that of operational shutdowns caused by adverse wind conditions, followed in order of importance by irrigation systems for bulk storage and roads. The urban or semi-urban situation of these small ports is, undoubtedly, a conditioning factor of this specialisation.

6.3.2. Medium-sized ports

The medium-sized ports adopt administrative measures as a priority. Particularly noteworthy are the mandatory regulations and disciplinary proceedings, demand requirements on emissions in conditions for the granting of concessions and signing of good practices agreements. These three measures have been implemented by 83% of medium-sized ports. On the other hand, within the two remaining categories (specific technical and operational and technical) all the ports have implemented irrigation systems for bulk storage and roads, within the first type of measure, and direct supervision at wharfs by Port Authority technicians within the second (83%).

6.3.3. Large and very large ports

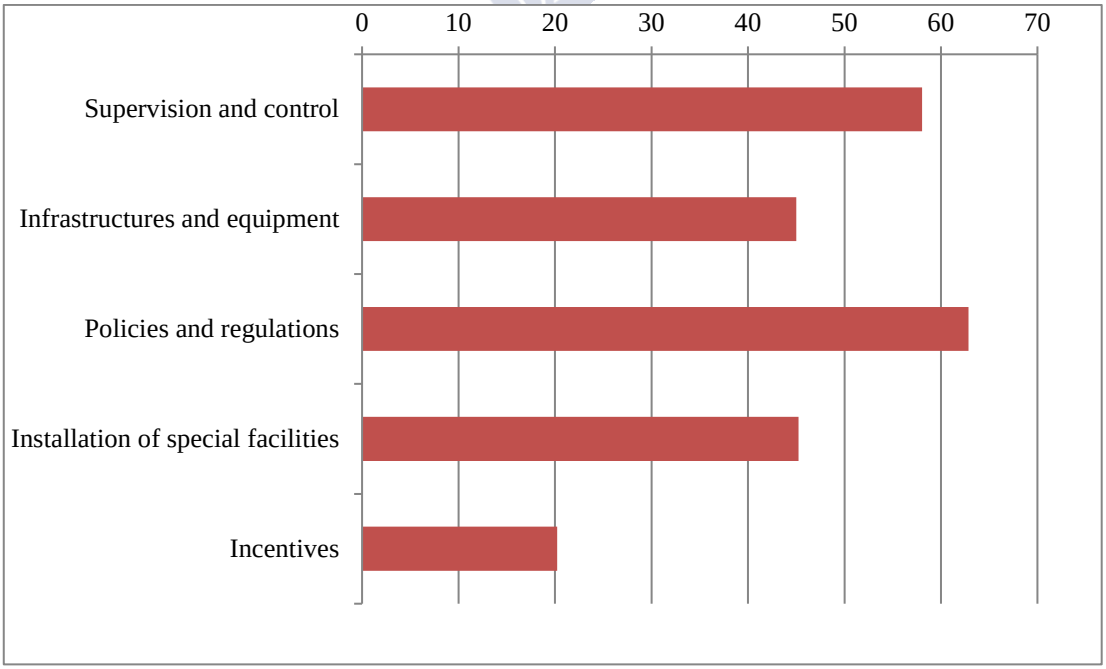
The 9 PAs that in 2016 moved over 15 million tonnes reveal a behaviour that is very similar to that of medium-sized ports with regard to the percentage that adopts administrative measures, but under different categories; in this case in systems to measure air quality parameters or regular campaigns, good practices guidelines and voluntary environmental codes and characterisation studies of the effect of port activities on air quality. This group of ports is not especially relevant in the adoption of specific technical measures, a group where irrigation systems for bulk storage and roads and wheel wash systems slightly stand out, and with a very low presence of the remaining measures in this category. Finally, a similar behaviour can be seen for operational and technical measures, where only a low number of measures with a certain degree of importance can be cited (direct supervision at wharfs by Port Authority technicians and monitoring port operator regulatory authorisations and notifications regarding emissions).

6.4. Results as per strategies.

Table 2 showed the classification of strategies for the control and reduction of emissions as per the three categories that group together the measures to be adopted by ports. Once the data has been used, the real degree of implementation of these strategies (Figure 3) can be calculated (for 2016 and for the entire Spanish ports system).

We can see that two types prevail: first of all, actions involving policies and regulations and supervision and control measures (implemented by 63% of ports) and, secondly, supervision and control measures (58%). Those that represent the provision of facilities and infrastructures do not reach even half of all Spanish ports; that is to say, only 45% of the PAs have contributed to infrastructures and equipment, and to the installation of special facilities. Finally, policy incentives to reduce air pollution were only adopted by one out of every five ports.

Figure 3. Strategies developed to reduce emissions and % of PAs that have implemented them (2016)



Source: Authors' own

7. Conclusions

This study has analysed the level of introduction of the specific measures that have been carried out by Spanish government ports of general interest to control and mitigate emissions within their facilities and improve air quality. The results obtained are in line with the research targets initially set forth. We have been able to determine that throughout the time period studied, which is the object of our study, PAs have based their strategy on the progressive introduction of operational and technical, administrative and specific measures. During the period in question, practically all of these measures have progressively increased.

Undeniable proof of the incidence of this behaviour since the enactment of the Ports Law and the introduction of the measures included therein can be seen in two aspects: firstly, the availability of strict information elements through the Sustainability Reports that each PA must submit annually, and secondly, the elements included in the new regulation to encourage and correct behaviours. The fact that the introduction of these measures at Spanish ports has evolved positively throughout the period studied for practically all of them adds even greater strength, if possible, to the importance of the development of the Law and to its commitment to sustainability. It would be of great interest in the future for Puertos del Estado to develop comprehensive information regarding the A06 indicator which provides information on complaints about air quality made by stakeholders relating to the PAs. This view would serve to contrast the coincidence of the strategies and measures adopted from such a perspective with the complaints made and their effectiveness.

On the other hand, the measures proposed by the methodology developed by Puertos del Estado are varied and have been classified under a number of categories. The adoption of administrative and specific technical measures is noteworthy of the entire

port system. Segmentation by groups of ports based on traffic volume (measured per tonnes moved), has made it possible to distinguish between the different ways ports tackle the problem of air pollution, revealing different action patterns. It has been established that the operations show considerable differences depending on the volume of port traffic: administrative actions are often consolidated for the entire Spanish port system, because it is the large and very large PAs that declare they implement measures of this type. On the other hand, the implementation of operative and technical measures is more developed in small ports. In larger ports, hardly any specific techniques against air pollution have been implemented.

Finally, the analysis carried out according to the grouping together of the measures and actions taking into account the five strategic categories is quite significant: the regulatory and supervision and control actions (of scarce economic relevance) have primacy; on the other hand, th

ose strategies that represent a commitment with the endowment of adequate infrastructures are implemented to a lesser extent, as are those that encourage third parties to use less contaminating elements. The results indicate the need for some ports to refocus their investment strategy in infrastructures, equipment and installation of special facilities, with the purpose of improving the quality of air in their premises: according to the Puertos del Estado's statistical information (indicator I37), Spanish ports as a whole invested 0.07% of the total investments for the period analysed (2011 – 2016) in environmental matters.

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ARTICLE 3 Port sustainability in Spain: the case of noise.

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Port sustainability in Spain: the case of noise.

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Abstract

The Spanish port system consists of 28 Port Authorities (PAs) that manage 46 ports, which transported 563.5 million tonnes of freight and 46 million passengers in 2018. They are almost all located in urban environments.

In all the ports complex activities are being carried out that have serious impacts on the environment. One of the most important is noise emission, which poses a risk to natural ecosystems and, above all, to human health.

This research focuses on the study of this problem for Spanish ports and is addressed from two sides: first, from an institutional perspective, namely, identifying the sources of noise pollution and the prevention, intervention and control strategies during the 2011–2016 period. And, secondly, comparing this analysis and perspective from the point of view of the PAs with the environmental performance detected and reported by the stakeholders.

The use, for the first time, of official information sources, verified and audited by the public entity Puertos del Estado, makes this analysis particularly relevant and reinforces the quality of the results.

This research confirms the effectiveness of the environmental sustainability planning measures, included in the new port regulations established in Spain in 2010, regarding the mitigation of the impacts of noise pollution arising from port activities.

Keywords: Port management, Environmental management, Noise, Indicators, Sustainability, Legislation

1. Introduction

It has been proven that noise pollution can pose serious risks to human health (Curcuruto et al., 2003, Basner et al., 2014). Therefore, noise is one of the most significant environmental problems faced by contemporary societies, especially in cities. Noise in urban environments comes, among other sources, from street, road and rail networks, industries, airports, and construction and port activities (Paschalidou et al., 2019).

A number of complex noise-generating activities are carried out in ports that have impacts on natural ecosystems, the environment and, directly, on the nearby urban population, port workers and passengers (Alsina-Pagés et al., 2018; Schenone et al., 2016). Consequently, these activities generate impacts on local communities, and the main sources of port noise (ship sirens, construction activities, loading and unloading activities, as well as vehicle traffic) pose a potential risk to health. In addition, the very nature of port operations, as in the case of roll-on/roll-off freight, both cars and lorries (RORO ramps), container handling, docked ships, etc., means that the intensity of this noise can vary depending on the source; therefore, a direct relationship could be established between different port activities and sources of noise pollution (Hyrynen et al., 2009). Likewise, in many cases, the emission of low frequency noise (which is associated with the greatest health problems), is a consequence of nocturnal port activities (Murphy & King, 2014).

In short, it seems obvious that if ports located in urban environments generate significant levels of noise pollution, these activities should be monitored and their impacts mitigated (Gupta et al., 2005, Dinwoodie et al., 2012). Also, as a result thereof, there may be a conflict of interest between the port development and the communities

where the port has its area of influence (De Langen, 2007). These conflicts should be solved with a smooth collaboration between the affected stakeholders and the Port Authority (PA), establishing basic courses of action to define and implement sustainable policies based on respect for the environment.

2. Importance of noise mitigation in port systems: experiences and proposed indicators

The World Health Organisation has indicated that exposure to noise has experienced a considerable increase in Europe, unlike other factors of environmental stress (Murphy & King, 2014). The first important experience in this subject concerning the port sector has been raised, at a European level, within the so-called Noise Management in European Ports project (NOMEPORTS, 2008). This project was sparked by the European directive 2002/49/EC (based, in turn, on the ISO 1996-1 standards) that established the reduction of noise in the influence areas of the ports as a matter of priority (EU, 2002). The NOMEPORTS project concluded with two main indications:

a) The influence areas of ports are large nuclei in the transport logistics chain and important economic centres. The Port Authorities (PAs) that manage them are showing a growing interest in the environment and in the sustainable development of ports. Industrial noise produced by port activities is a very significant problem.
b) In this context, sustainable development, focused on this specific problem, must be equipped with practical and effective tools: the so-called strategic noise maps.

Furthermore, the ESPO (European Sea Ports Organisation) regularly submits a ranking of the most significant environmental impacts of the ports. Noise is one of the main

environmental problems highlighted by the PAs: in the 2009 report (ESPO, 2012) it was identified as the number one priority and from 2016 to 2018, it was placed third on the ranking of environmental impacts of the ports (ESPO, 2018).

There is a certain complexity to the problem of noise pollution in port systems, depending on the port situation and its specialisation. The TFK Transports Research Institute (2013), in a document entitled "Noise as an environmental challenge for ports" (PENTA project), concludes that the study of the problem of port noise transcends beyond the mere measurements of decibels and, without underestimating this basic part of the analysis, the noise must be addressed from a more comprehensive point of view, including economic, legal, medical or architectural aspects. Namely, addressed from the comprehensive perspective of sustainable development. The aforementioned report indicates that the most common sources of noise in ports are the following:

a) Movement of port machinery.

b) Movement of trucks.

c) Rail traffic.

d) Ramps between vessels and docks.

e) Handling of freight, containers and bulk cargo.

f) Docked vessels.

As practical guidelines, the report suggests operational measures and control tools, highlighting the importance of collaboration between the different stakeholders involved.

More recently, from this institutional action perspective, the European Union has promoted the cooperative project 'Managing the Environmental Sustainability of Ports for a durable development' (MESP), funded by the ENPI CBCME MED programme. This project aimed to reduce the levels of noise, air and water pollution arising from port activities. It was carried out by six partners from four countries on the Mediterranean Coast (Lebanon, Jordan, Italy and Greece) and was finalised in 2015 (Schenone et al., 2017). An interregional programme, funded by the INTERREG Italy - France (Maritime) EU programme, is currently being carried out to develop, until 2021, sustainable-development management of the different ports that make up the interregion of the Mediterranean coast of France and Italy, in order to coordinate actions to control and reduce the noise caused by port activities. These ports have the singularity of being located in urban environments, being of different sizes and presenting different specialisations in their traffic (Schenone et al., 2019).

This pioneering action in the coordinated and comprehensive study of the noise pollution problem area for a group of European ports is being carried out, in turn, through six projects:

a) REPORT (Rumore E PORTi). Based on the European noise directive 2002/49/EC, by defining new algorithms and methodologies, it seeks to design suitable strategies in the cross-border area to take action against noise pollution in ports from the field of sustainability (Borelli & Schenone, 2018).

b) The MON ACUMEN (MONitorage Actif Conjoint Urbain-MaritimE de la Nuisance). Its main objective is to monitor the sources of noise in ports (vessels, railway traffic, heavy vehicles and others) and to establish suitable corrective measures in the ports of La Spezia, Livorno, Cagliari and Bastia (Licitra & Ascari, 2018, Licitra et al., 2019).

c) RUMBLE (Réduction du bruit dans les grandes villes portuaires dans le program maritime transfrontalier). Its aim is to monitor noise sources and set up infrastructure to reduce noise pollution in large commercial ports such as Cagliari, Genoa, Nice, and Livorno (Licitra et al., 2019).

d) DECIBEL (Dépollution acoustique des centres portuaires urbains et insulaires). In this case, the goals of tackling noise emissions from the ports promoted by the MESP programme are applied to small ports oriented towards sport and tourism, such as Ajaccio, Ille Russe, Olbia, Portoferraio and Giglio.

e) LIST-PORT PROJECT (Limitazione Inquinamento Sonoro dal Traffico nei porti commerciali). It aims to reduce noise pollution in commercial ports and related logistics platforms. It is based on the evaluation of the use of integral management systems to verify how they affect the reduction in traffic volume and, therefore, noise emissions in ports and urban areas.

f) TRIPLO PROJECT (TRASPORTI e Collegamenti Innovativi e Sostenibili tra Porti e Piattaforme LOgistiche). One of its particular features is that it analyses the noise sources in the areas between the ports and the logistics platforms. It seeks to reduce noise pollution in these areas through a cross-border strategy to regulate traffic flow, especially in logistics platforms.

Conversely, as a general rule, academic contributions from a sustainability perspective do not present the problem of noise pollution of the port system in an individual framework, but together with other significant environmental impacts and within comprehensive environmental management systems.

Likewise, different proposals for environmental performance indicators have been developed, dealing with the problem of environmental policies focused on the control,

management and mitigation of noise impacts in ports, among others (Peris-Mora et al., 2005; Saegsuoavanich et al., 2009; Lirn et al., 2013; Puig et al., 2014; Puig et al., 2015). More recently Puente-Rodriguez et al. (2015), proposed indicators based on four aspects: water quality, energy consumption, noise, and air quality; Antão et al. (2016) defined a battery of port sustainability indicators based on safety, occupational health and environmental aspects. Finally, the most concrete approach to the problem of noise pollution has been developed by Puig et al. (2017), building a system of port performance indicators to apply to as many ports as possible and based on the contents of different projects and studies. They combine different sources of indicators, PPRISM Project, EMS (Standards for Environmental Management Systems), port legislation, etc., as well as the questionnaires of the different ESPO projects. A total of 22 indicators to measure the noise impact of port activities are included in their proposal.

On this issue, the perspective of KPIs (Key Performance Indicators), which are becoming increasingly important, cannot be ignored. In this context, noise pollution (a traditional problem in ports) cannot be separated from the subject of port sustainability, which is understood to be multidimensional, as the level of integration of regulatory, managerial and environmental frameworks will lead to rating all ports as Green Ports (Di Vaio & Varriale, 2018; Di Vaio et al., 2018). Accordingly, there is a need to highlight the first conclusions of the new Strategic Framework of the Spanish Port System (Puertos del Estado, 2019c), which analyses the effectiveness of the Balanced Scoreboard in Spanish PAs as it currently stands and how the specific development of the KPIs is included in said framework.

In any case, it should be noted that noise pollution produced by port systems is a subject that has been little studied from a sustainability perspective (beyond indicator

proposals) but it has been from a technical perspective (Hyrynen et al., 2009) or for very specific or isolated cases (Murphy & King, 2014, Kalami et al., 2015, Schenone et al., 2016, Santander et al., 2018, Alsina-Pagés et al., 2018, Paschalidou et al., 2019).

With regard to the Spanish port system, it is made up of 28 Port Authorities, which manage 46 ports. During 2018, 563.5 million tonnes of freight were transported, and 46 million passengers were accounted for (Puertos del Estado, 2019b). Almost all these ports are located in urban environments, which means that they generate a series of negative externalities for their influence areas. Noise pollution is one of them (Llorca, 2014).

The concern for the different environmental impacts was introduced in the Law on State Ports and the Merchant Marine 33/2010, of 5 August, which includes the duty to annually prepare a Sustainability Report (Martín Bermúdez et al., 2019). These reports include a series of indicators in four dimensions: institutional, economic, social and environmental. Within the environmental dimension, four qualitative indicators, where PAs report their concerns about the main sources of noise and the measures applied to mitigate these impacts, are included. Its scope and content will be widely developed in the relevant methodological section of this paper.

3. Objectives and methodology

In literature consulted, it is difficult to identify the main sources of noise pollution that are relevant to ports, and even much more difficult to identify the specific measures that have been implemented to mitigate this type of pollution. However, based on the use and analysis of the relative data of said indicators from the Sustainability Reports of the Spanish PAs for 2011 to 2016, the following objectives can be proposed:

a) Identify the main sources of noise in ports and their significance.

b) Verify the role of stakeholders, especially concerning the complaints received in the PAs about the noise pollution that affects them directly.

c) Analyse which strategies have been followed and the priority measures adopted to eliminate and/or mitigate it in order to establish an environmental policy template on noise pollution in the Spanish port system.

d) Segment the different groups of ports according to their size to analyse the values of the aforementioned indicators, their problems and concrete measures.

In the official methodology developed by Puertos del Estado for ports under their responsibility to draw up their own Sustainability Reports, the environmental dimension is made up of a total of 35 performance indicators (Puertos del Estado, 2019c). Four of them (those identified with codes A18, A19, A20 and A21) provide information regarding noise identification and management. The details of the contents of each one are summarised below:

- A 18.- It requires each PA to identify the main sources of noise present in the ports and their relevance (ranked from 0 to 10 according to their significance), submitting ten activities considered possible sources of noise pollution. These activities are similar to those considered by Gupta et al. (2005), Hyrynen et al. (2009) or the aforementioned report of the Transports Research Institute (2013). The classification of the different sources of noise in the port areas is shown in Table 1.

  The ranking given to each source by each PA is submitted in Table 2. The ranking given to this has been made grouping the frequencies of the answers given for each item in five identical range intervals, as the State Ports Methodology establishes a scale of 0 to 10.

- A 19.- It reflects the complaints arising due to noise pollution at the ports. They are classified according to three interest groups (local residents, city councils and members of the port community), as well as the identification of the activity causing these complaints. The establishment of the indicator had certain informational shortcomings in 2011 and 2012, consolidating its structure for 2013 and following years, when it was processed as mandatory for ports.

Table 1 Sources of noise emissions in ports

Type of activity	
Traffic	Trucks
	Railway
Handling activities	Scrap
	Containers
Movement of RORO terminals	
Port machinery	
Industrial activity concessions	
Docked ships	
Works	
Leisure facilities	

Source: autors' own based on environmental indicator A18 (Puertos del Estado, 2019c)

Table 2 Incidence levels of noise emissions

Ranking	
1-2	High
3-4	Medium-high
5-6	Medium
7-8	Medium-low
9-10	Residual

Source: autors' own based on environmental indicator A18 (Puertos del Estado, 2019c)

- A20.- This is a descriptive indicator, requiring the situation of each port concerning the preparation of the noise map and the noise action plan to be indicated. It accurately reflects the philosophy and contents of the aforementioned NOMEPORTS Project (2008).

- A21.- This requires the measures that have been implemented to mitigate noise pollution, arising from the complaints and the port activities themselves, to be declared. Following the guidelines adopted by Puertos del Estado for the environmental pollution indicator A7 (Puertos del Estado, 2019c)—which refers to the measures implemented by the Port Authority to control emissions linked to the activity of the port as a whole—they have been classified into three types: a) Administrative, b) Operational or technical, c) Specific techniques (Martín Bermúdez et al., 2019). The 11 measures included in each of these categories are included in Table 3.

Table 3 Polluting air emissions: measures implemented by the Port Authorities to improve noise quality

Administrative	Operational or Technical	Specific techniques
1. Stable noise measurement networks.	1. Surveillance/inspection of operations by PA personnel.	1. Installation of noise screens.
2. Noise-measurement campaigns.	2. Speed limits in the port roads.	2. Improvement of road surfaces to reduce noise emissions.
3. Standards or good practices in loading and unloading scrap or containers.	3. Activity restrictions during the night.	3. Access improvements or reorganisation of internal circulation to reduce truck traffic through urban centres.
4. Maintenance conditions for machinery in service contracts and concessions.	4. Rearrangement of port activity to avert noise sources from urban areas.	

Source: autors' own based on environmental indicator A21 (Puertos del Estado, 2019c)

The Ports Act includes the obligation to prepare Sustainability Reports. At present, there are already results for a sequence of six consecutive years (2011-2016). The sources of information used in this paper have been provided by Puertos del Estado and are based on the use and verification of said reports by the aforementioned body.

The calculation operations for the six years to be analysed (2011 - 2016) are based on the following guidelines:

a) Based on the data of Indicator A18, the preparation of a matrix of 10 x 28 values for each year concerning the different sources of noise pollution (10) and numbers of PAs (28) is carried out, which, taking into consideration the existence of five incidence levels, represents 1,680 recoded data for each of the six years considered.

b) A second matrix has been drawn up, coding in 11 categories the complaints made by the interest groups on noise emissions from the ports, which has led to the processing of 1,848 values per year (Indicator A19).

c) Finally, according to the Puertos del Estado Methodology, 1,848 data items per year, corresponding to the 11 measures implemented in the period analysed by the 28 PAs to reduce noise pollution have been processed (Indicator A21). All this data, in turn, is used for each of the three categories in which the ports are grouped according to their size.

4. Analysis of results

4.1. Incidence levels of noise from the port perspective

4.1.1. Spanish port system

The mining of the first answers indicated by the PAs enables a clear pattern of the sources of noise pollution in the Spanish port system during the period analysed to be established (Table 4):

a) There are three common sources of noise with a high or very high incidence in virtually all ports. They are, in order of importance: truck traffic (63.7% between both scales), port machinery (57.1%) and from docked ships (41.1%).

b) Noise sources that depend on the traffic, infrastructure and specific equipment characteristics of each port, with incidence in various ranges of degrees are the following: scrap handling, movement of containers, RORO terminals and rail traffic.

   Good evidence of the influence of the typology of each port on these noise sources is that they are not present in the environments of between 42% and 58% of the ports.

c) Noise pollution with an important but diffuse impact, with a presence in 60% of the ports, but with different incidence levels: industrial work and activity concessions.

d) Finally, the sources of noise with lower incidence are leisure facilities, which are not present in 70.2% of the ports and, consequently, with significant low or residual levels from the perspectives of the PAs.

4.1.2. Effect of port size

The analysis of the environmental performance that ESPO regularly carries out usually divides the ports into four groups according to the number of tonnes of freight that they move annually (Puig et al., 2017). In order to maintain statistical confidentiality and following a similar criterion, three categories for the 28 PAs that make up the Spanish port system are established (Martín Bermúdez et al., 2019):

a) Small: those that move less than 5 million tonnes/year (13).

b) Medium: between 5 million and 15 million tonnes/year (6).

c) Large and very large: more than 15 million tonnes/year (9).

Segmenting the ports according to this classification, an analysis is then made on whether there are differentiated sources of noise pollution. For this purpose, Figure 1

shows the main sources of noise present in the different port categories and which PAs have considered high or medium-high priority over the time series under study.

Table 4 Average incidence levels of the noise sources according to the source of origin (2011-2016)

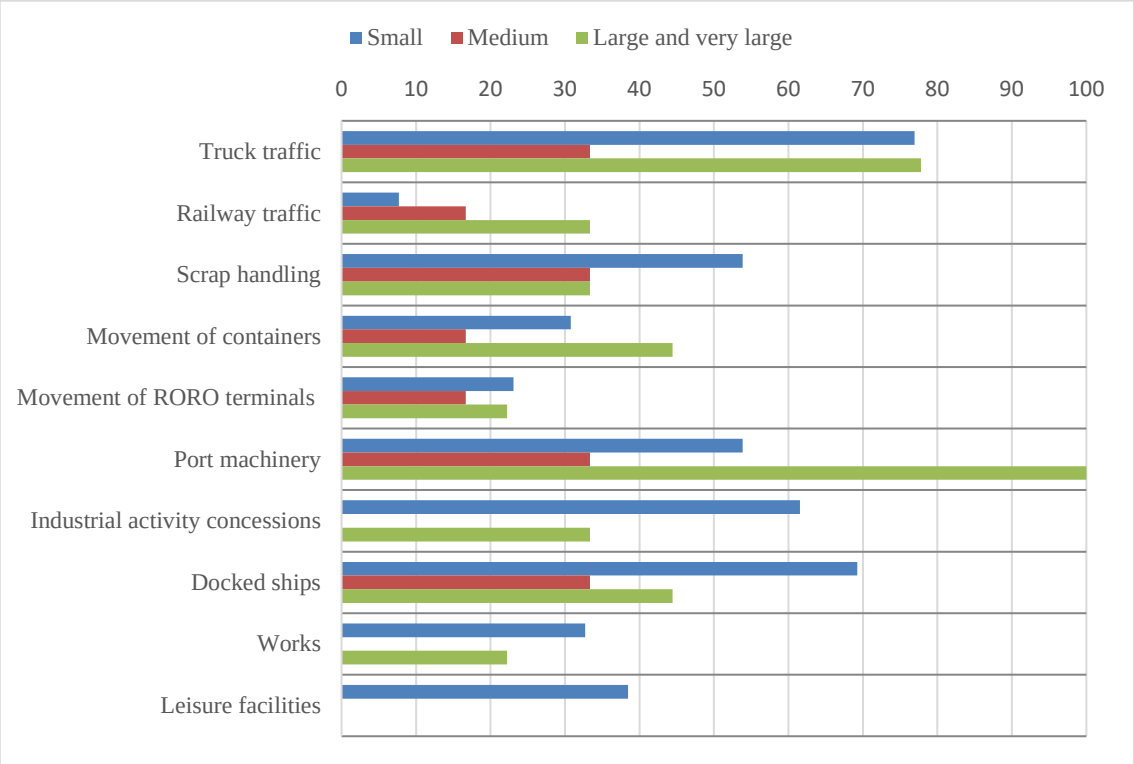
	Incidence levels (% ports)					
Activity	High	Medium-high	Medium	Medium-low	Residual	Not present
Truck traffic	45.2	18.5	7.7	3.6	0.6	24.4
Railway traffic	6.0	7.6	14.0	7.1	7.7	57.6
Scrap handling	19.6	6.0	6.0	11.8	4.2	52.4
Movement of containers	13.1	19.1	9.5	16.1	0.6	41.6
Movement of RORO terminals	8.7	13.0	8.9	11.6	6.0	51.8
Port machinery	34.5	22.6	9.5	3.0	0.0	30.4
Industrial activity concessions	19.1	13.0	11.9	11.9	4.2	39.9
Docked ships	19.7	21.4	16.6	6.6	3.6	32.1
Works	8.4	11.9	27.5	9.6	3.2	39.4
Leisure facilities	8.3	4.2	0.6	6.6	10.1	70.2

Source: autors' own based on environmental indicator A18 (Puertos del Estado, 2019c)

The first observation that can be made is that in Spain the nine ports considered as small are located in very central urban environments. It is not surprising therefore that, in this order, the main concerns of the PAs in this type of pollution are truck traffic (77%), noise from docked ships (69%), industrial activity concessions (62%), scrap handling and port machinery (54% in both cases) and leisure facilities (38%). It can be deduced that, in this port category, concerns about noise emissions extend to all activities.

With regard to medium-sized ports, only a third of the total of those included in this category (33%) reports the presence of a significant incidence of noise pollution from truck, scrap, machinery and docked ships. And none of them report noise from entertainment and construction sites.

Figure 1 Primary sources of noise pollution (high or medium-high incidence) by port groups according to their size (%)



Source: authors' own

On the other hand, the larger ports are conscious of the source of noise pollution that comes from the port machinery (100%); In addition, 78% attribute it to truck traffic and 44% to that from docked ships or the movement of containers.

4.2. Noise incidence levels from the stakeholders' perspective

4.2.1. Spanish port system

Since 2013, it has been mandatory for PAs to indicate in their annual reports the number, reason and source of the complaints received for noise pollution arising from their facilities and activities (Indicator A19). It is important to highlight that the methodology itself accurately ranks the sources of noise relevant to the PAs and the sources of noise pollution indicated by the stakeholders, which enables an exhaustive analysis of the adequacy of noise mitigation policies and strategies with all interest

groups. Likewise, this methodology specifically identifies four categories of stakeholders:

a) Local residents from the influence areas near the port facilities.
b) Members of the port community itself.
c) City council where the port is located.
d) Complaints from unknown informants, made anonymously or as suggestions by people who do not identify themselves.

For the entire Spanish port system, in the period considered, 381 complaints were received and accounted for regarding noise from port activity, of which 64.6% were made by unidentified stakeholder, 33.4% by residents and only 1% by both the port community and the municipal authorities. These last two stakeholders have roles and interests different from the majority of the complainants, and as they are present in the management and administration bodies of the Spanish PAs by law, they have other instruments to channel their complaints or suggestions and proposals within their own port organisations in matters related to noise pollution and prevention and mitigation strategies. Hence their scarce presence in the figures collected by the PAs in their Sustainability Reports. In the following sections a detailed analysis of these results will be made.

4.2.2. Effect of port size

Figure 2 includes the percentage distribution of the origin of the complaints of the stakeholders according to the classification adopted and for each group of ports. First, it should be noted that in small ports (undoubtedly due to their proximity to urban centres), 77% of complaints come from local residents; 17% from unidentified whistleblowers and 6% from the port community itself. There were no complaints from the city council during the period. In the medium-sized ports, 45% of the

complaints for noise pollution came from local residents, 33% were from unidentified sources and 22% from city councils. In this case, the port community did not file any complaints.

Finally, in large and very large ports, 57% of complaints came from anonymous whistleblowers, 36% from local residents and 7% from the port community. There were no complaints from municipal authorities.

It is important to deepen the analysis by finding out which sources of noise pollution each of the stakeholder groups have complained about. Table 5 shows the distribution of the percentages of complaints according to the activity causing the source of pollution. The most significant results obtained by port categories are detailed below:

a) *Small ports:* there are two very clear sources: entertainment facilities (complaints that come mostly from local residents and represent 33.3% of the total complaints of this group) and docked ships (20.5% of complaints from local residents and 10.3% of unidentified authorship). For ports of this size, neither the city councils nor the port community presented any complaints.

b) *Medium-sized ports:* all stakeholders have presented some type of significant claim for noise pollution: local residents, who in 20% of cases complain about the RORO terminals; the city councils, with the same percentage for the noise coming from the movement of containers; the port community, which complains about the leisure facilities (13.3%) and, finally, the unidentified stakeholders that make up 20% of noise complaints from unidentified sources.

c) *Large and very large ports:* as for the first of the categories, it is the local residents who concentrate their concerns on a greater number of different activities. The most noteworthy, docked ships and leisure facilities (12.5% of

complaints). Similarly, complaints of unidentified origin are mainly about building work (25%) and the noise coming from the docked ships (18.8%).

Figure 2. Origin of complaints according to the type of stakeholders and the size of the ports (%)

Source: authors' own

4.3. Mitigation strategies and measures implemented

Once the main sources of noise in Spanish ports identified by the PAs and stakeholders have been defined, the investigation is completed analysing the strategies and measures that have been carried out to mitigate the effects of said noise pollution in the period considered.

Table 5 Percentage of relevant complaints by interest groups according to the activity generating the noise and size of the ports (2011-2016). (S = small; M = medium; G = large and very large)

Activity	Local residents			City council			Port community			Unidentified whistleblowers		
	S	M	L	S	M	L	S	M	L	S	M	L
Truck traffic												
Railway traffic	2.6		6.3							2.6		
Scrap handling	5.1									2.6		
Movement of containers					20.0							
Movement of RORO terminals		20.0										
Port machinery	2.6											
Industrial activity concessions	5.1		6.3						6.3			
Docked ships	20.5	6.7	12.5						6.3	10.3		18.8
Works											6.7	25.0
Leisure facilities	33.3	6.7	6.3	2.6				13.3		2.6	6.7	
Unidentified	7.7		12.5							2.6	20.0	
Total	***76,9***	***33,3***	***43,8***	***2,6***	***20,0***	***0,0***	***0,0***	***13,3***	***12,5***	***20,5***	***33,3***	***43,8***

Source: autors' own

4.3.1. Spanish port system

Figure 3 shows the percentages of ports that have adopted noise mitigation strategies and their evolution over the period analysed. Several important issues can be highlighted: First, there is a positive trend of the percentage of ports that have adopted them depending on the time frame, namely, according to the Ports Law requirements that have been gradually implemented from 2011 onwards. This growing behaviour shows another characteristic: it has been developing practically in parallel for each of the three categories considered. In short, the Spanish PAs are choosing to carry out increasingly comprehensive noise reduction and moderation policies, as the period under consideration progresses. Secondly, the Spanish PAs have opted primarily for control measures for operational and technical noise pollution, and in 2016, 50% of Spanish ports had already implemented them (in 2011 this percentage was only 32%).

It should be noted that this category includes surveillance activities, speed limits and activity restrictions and access improvements. Thirdly, there is a commitment to the implementation of specific techniques and, finally, to administrative actions. In these two categories, the percentage of ports conforming to them practically doubled in the period considered. A breakdown of the specific actions by each category carried out by Spanish ports this year can be seen in Puertos del Estado (2019c).

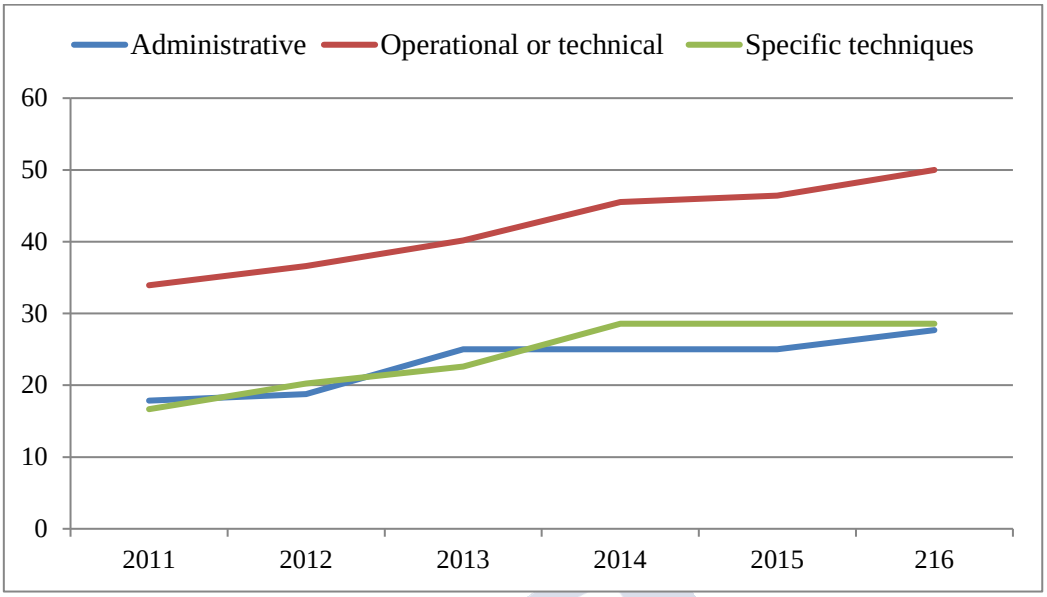
The complementary analysis of the results of the A20 Indicator enables us to relate these findings to whether or not there is a noise map: it coincides with the fact that in 2016, 50% of the ports had already prepared this environmental management instrument while 14% were in the development phase. The requirements of the internal management of the port authorities and the demands of the municipal plans are among the reasons why the maps have been made (Puertos del Estado, 2019c).

4.3.2. Port groups

The analysis segmented by port groups according to their size is carried out for the measures implemented by the PAs in the last year of the analysed period, as it implies the accumulated value of all the measures implanted in all this space of time.

Figure 4 includes noise pollution mitigation strategies in ports carried out both by size and by specific measures. These have been classified in the chart in a clockwise direction to match the columns included in Table 3. For further research, these measures have been identified with the initials relative to the category in which each of them was included: A = Administrative; O/T = Operational or Technical; ST: Specific Techniques. The detailed results are discussed below.

Figure 3 Trend in the percentage of PAs that have implemented measures to control and reduce noise pollution (2011-2016)



Source: autors' own based on environmental indicator A21 (Puertos del Estado, 2019c)

a) *Small ports.* The ports included in this group are characterised by the almost total lack of administrative measures to mitigate noise pollution; relatively speaking, they have opted for operational or technical measures: 50% of PAs carry out surveillance and periodic inspections, 38% have speed limits and 36% have improved access or have reorganised their activity to reduce noise. Finally, a third of the ports have limited their activity during the night. The adoption of measures based on specific techniques highlights the fact that 46% of the ports have made improvements to road surfaces.

b) *Medium-sized ports.* The behaviour of the six ports included in this group is practically identical to that of small ports regarding the use of strategies based on administrative and operational and technical measures, as can be seen in the figure. However, there are some differences in the adoption of specific techniques: the improvement in access or reorganisation of activities has been adopted by 44% of the ports and 30% have proceeded to install noise screens.

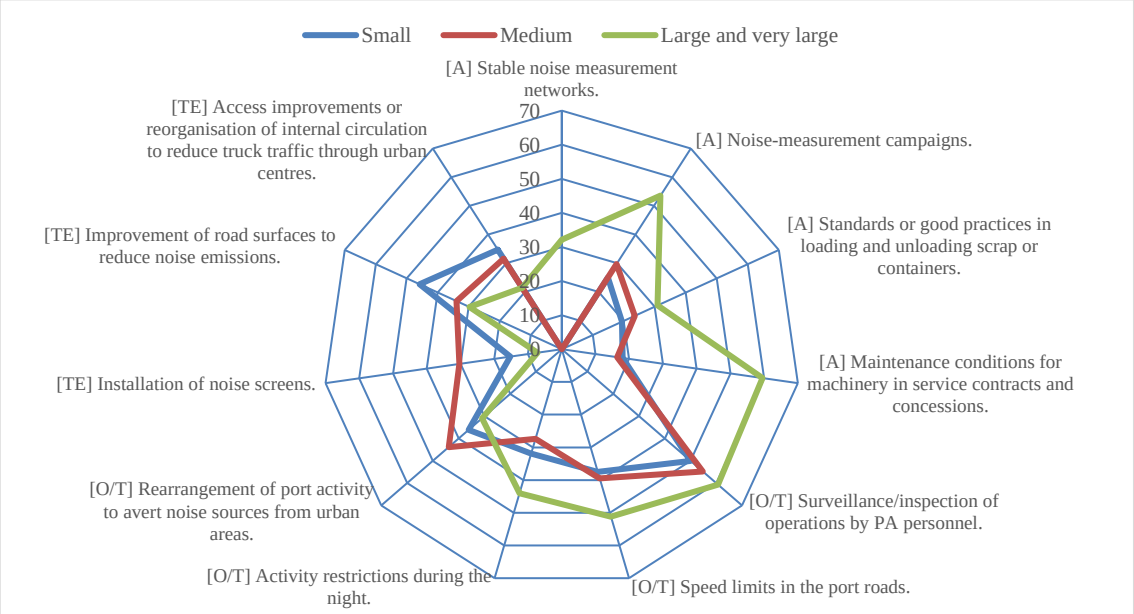
c) *Large and very large ports.* The special characteristics of the nine ports of the Spanish system included in this category mean that the strategies for combating noise pollution differ considerably from the other ones implemented in the other groups. First, it can easily be seen that they far outnumber small- and medium-sized ports both in administrative and technical measures: they are the only ones in the total number of Spanish ports in which 32% have proceeded to install noise-measurement networks; 60% demand maintenance conditions in services and concessions, precisely in ports that indicate they carry out surveillance and periodic inspections and, finally, it must be highlighted that half of them have established speed limits in the port roads.

With regard to the implementation of measures with specific techniques, the behaviour is the opposite: most significantly, only a third of the ports state that they have made improvements to road surfaces to reduce noise.

5. Conclusions

This study is conceived as the first comprehensive analysis, from a sustainability perspective, that has been carried out on noise pollution in all the Spanish ports. It also has specific features: it enables a diagnosis of the causes and origins of noise sources and identifies the management, control and prevention policies being implemented. The analysis carried out over a period of 6 years serves to give an evolving vision of the different strategies and the fact that it is based on the mining of official data, verified and contrasted by the administration, guarantees its reliability. The dual point of view between the PAs themselves and the stakeholders regarding the perception of noise pollution sources makes it even more coherent.

Figure 4 Trend in the percentage of PAs that have implemented measures to control and reduce noise pollution by port groups according to their size (2011-2016)



Source: autors' own

As a reflection on the results achieved, it is important to highlight out that Spanish PAs consider noise from truck traffic, port machinery and docked ships, among others, as the main sources of noise pollution. These noise sources are among those referred by the Transport Research Institute (2013) and those recently tested in the ports of Cagliari, Genoa, Nice and Livorno within the research of the European project RUMBLE (Licitra et al., 2019). The analysis by groups of ports according to their size determines that all of them follow a pattern similar to the system as a whole with some exceptions: the small ports understand truck traffic and docked ships as more important sources of noise pollution of their facilities, following the common pattern of the whole system. However, they also understand leisure facilities in their installations to be sources of noise. Larger ports cite port machinery (in all of them) and truck traffic as conflicting elements. Finally, medium-sized ports pinpoint very few sources as high or very high incidence.

It is especially interesting to contrast the perception of stakeholders with the position of the PAs in this matter. Note that there is an active presence of unidentified whistleblowers and residents of the vicinity of the ports, and virtually no activity from the city councils and members of the port community itself outside the administration and management of the PAs. As an excerpt, two issues could be highlighted:

- There have been no complaints or very few for noise sources from the two categories that all PAs consider as primary sources: truck traffic and port machinery. This undoubtedly means that the measures adopted by the ports have proven effective in these two categories.
- Stakeholders show their concerns for two well-differentiated sources: leisure facilities (reported by local residents and especially in small ports) and docked ships (in this case, on a broad front, although more pronounced in smaller ports). It should be noted that the responsibility for the regulation and closing hours of leisure facilities in Spain does not lie with the PAs and falls under the responsibility of regional authorities and city councils.

The investigation has been completed with an analysis of the measures adopted by the PAs. It has been determined that there is a predominance of operational and technical actions over the other categories. However, considering the size of the ports, a double situation occurs: small and medium-sized ports opt for operational and technical measures; and the big ones prefer to use administrative routes and specific techniques. Comprehensive readings of all measures implemented point more towards management and prevention than to investment in infrastructure (for example, the cases of the very limited presence of actions such as noise-measurement networks, installation of noise screens, improvements of accesses and roads, etc.).

Finally, to conclude with several aspects arising from the research carried out:

a. First, the positive impact of the new Spanish port regulations on the impact and mitigation of noise pollution in ports of general interest is clearly demonstrated: the identification of the source of noise, the decision-making on the strategies to adopt and the progressive increase in the measures carried out during the period considered determines this. However, even taking into account the positive impact that the new standard has had on the measures adopted by the PAs to mitigate noise pollution, it is nonetheless true that many of them still have a long way to go. The extension, which could become mandatory, of an administrative measure, such as the installation of stable measurement networks in each port, would supplement the drafting of the noise maps already initiated, and would serve to establish more concrete action strategies against noise pollution.
b. In the adopted measures, cross-sectional guidance prevails, enabling the action to be focused on several noise-generating activities (not only on the main one); but these measures should be complemented by the provision of infrastructure, which would require a longer time frame. Similarly, it would be worthwhile to implement incentive measures; for example, the use of quieter port machinery, the use of trucks with low levels of noise emissions, as well as investments to provide, in general, measurement networks or screen installation. Due to the limited provision of stable measurement networks, an important noise management tool (a basic element of any environmental management system) is lacking (Dinwoodie et al. 2012).
c. The participation of the interest groups should be highlighted as a basic element in the planning of port sustainability. Therefore, the identification and selection of a greater number of stakeholders should be encouraged in line with the

proposals of Le et al., (2014) and Van Thanh (2016). And if, until now, the opinions of these groups is gathered in a declaration of complaints, to avoid the existence of future conflicts between those and the PAs, solutions should be sought based on smooth communication between these interest groups and the port authorities—in the direction expressed by de De Langen (2007)—which would lead to a strengthening of information-gathering channels (Hall et al., 2013).

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ANNEX: Original Published Papers

Publication 1.

González Laxe, F, Martín Bermúdez, F., Martín Palmero, F. & Novo-Corti, I. (2019) Sustainability at Spanish ports specialized in liquid bulk: evolution in times of crisis (2010–2015), *Maritime Policy & Management*, 46:4, 491-507.

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Publication 3.

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