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Editorial Note

Cartagena de Indias, July 19th, 2018.

In this edition the Ship Science and Technology Journal, opens a new volume with the scientific articles presented at the V International Ship Design and Naval Engineering Congress, held in Cartagena - Colombia as a part of the Colombiamar Fair, 2017.

For this issue, the Journal includes publications related to: strategic planning in the construction of an OPV (offshore patrol vessel), cluster platforms for the shipyard sector in the Colombian Caribbean, competitiveness in the sector through the development of logistical capabilities, identification of projects for the development of the fluvial sector and the socio-economic impact of intermodal connections in the country.

As a strategy to improve the visibility and impact of the journal, this time we are pleased to announce to our authors and readers that The Ship Science and Technology Journal has been added to the Directory of Open Access Journals - DOAJ, as well as to the Scientific Content Platform *REDIB* (Ibero-American Network of Innovation and Scientific Knowledge) and the Regional Online Information System for Scientific Journals of Latin America, the Caribbean, Spain and Portugal - *LATINDEX*. In addition, the journal has been included in the bibliographic database B*ASE - Bielefeld Academic Search Engine, JournalTOCs, Ulrich's Directory*, in the Information Matrix for the Analysis of Journals *MIAR*, and in specialized databases such as *Marine Technology Abstracts*.

We thank to all our readers, authors, members of the editorial committee and members of the scientific committee for their contributions in the preparation, review, edition and dissemination of scientific material published by the journal; its valuable contribution increases every day the quality and impact of the publication and brings us closer to the goal of being positioned as one of the best scientific journals on ship design, naval architecture, and naval, marine and ocean engineering.

Captain (Ret) CARLOS EDUARDO GIL DE LOS RÍOS
Ship Science and Technology Journal Editor

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Nota Editorial

Cartagena de Indias, 19 de Julio de 2018.

En esta edición la Revista Ciencia y Tecnología de Buques, abre un nuevo volumen con los artículos científicos presentados en el V Congreso Internacional de Diseño e Ingenieria Naval realizado en el año 2017 en la ciudad de Cartagena – Colombia en el marco de la Feria Colombiamar.

Para este número, la revista cuenta con publicaciones referentes a la planificación estratégica en la construcción de una OPV (offshore patrol vessel), plataformas de clúster para el sector astillero en el caribe colombiano, competitividad en el sector a través del desarrollo de capacidades logísticas, identificación de proyectos para el desarrollo del sector fluvial y desarrollo e impacto socio-económico de conexiones intermodales en el país.

Como parte de la estrategia de visibilidad e impacto, en esta oportunidad nos complacemos en anunciar a nuestros autores y lectores que la revista ha sido agregada en el Directorio de Revistas de Acceso Abierto – DOAJ, en la Plataforma de Contenidos Científicos *REDIB* (Red Iberoamericana de Innovación y Conocimiento Científico) y en el Sistema Regional de Información en Línea para Revistas Científicas de América Latina, el Caribe, España y Portugal - *LATINDEX*. Además se ha extendido la divulgación de la revista con su inclusión en las bases de datos bibliográficas *BASE - Bielefeld Academic Search Engine, JournalTOCs, Ulrich's Directory*, en la Matriz para el Análisis de Revistas *MIAR* y en bases especializadas como *Marine Technology Abstracts*.

Agradecemos a todos nuestros lectores, autores, miembros del comité editorial y miembros del comité científico por sus aportes en la elaboración, revisión, edición y divulgación del material científico publicado por la revista, su valiosa contribución incrementa cada día la calidad e impacto de la publicación y nos acerca a la meta de ser posicionada como una de las mejores revistas científicas en temas de diseño, ingeniería y arquitectura naval, marítima y oceánica.

Capitán de Navío (RA) CARLOS EDUARDO GIL DE LOS RÍOS
Editor revista Ciencia y Tecnología de Buques

Towards a technology and agglomeration platform of the colombian caribbean shipyard sector

Hacia una plataforma tecnológica y de aglomeración del sector astillero del caribe colombiano

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Jesús Alberto Villamil [1]

Abstract

The need to create the conditions to improve the productivity and competitiveness of the shipyard sector in the Caribbean Region, is framed by the greatest challenges and technological advances, especially in the adoption of technologies in the naval industry, which implies the making of investment decisions based on the development of research and development activities. Agglomeration (clusterization) trends tend to define articulating and animating agents that allow the establishment of a technological and competitiveness agenda (technological platform) for the adoption of a new model based on innovation and technological development. The world-wide experiences of the role of the generation of technologies are varied, not only from the private but also public scope for the improvement in competitiveness in the shipyard sector. In the Caribbean region, thanks to COTECMAR's trajectory, some of its capabilities could be oriented to define, on the one hand, the medium- and long-term strategy for the shipyard sector, and on the other, to establish a market and technology intelligence center and finally to define itself as an animator between the different public and private actors that lead to the development of important technology projects based on innovative processes of transfer and commercialization, without losing its mission of being a guarantor of National Security and Defense.

Key words: Shipyards; cluster; agglomeration; Technological platform.

Resumen

La necesidad de crear las condiciones para mejorar la productividad y competitividad del sector astillero en Colombia, se enmarca en los mayores desafíos y avances tecnológicos, especialmente en la adopción de tecnologías en la industria naval, lo que implica la toma de decisiones de inversión fundamentadas en el desarrollo de las actividades de investigación y desarrollo. Las tendencias de aglomeración (clusterización) pasan por definir agentes articuladores y animadores que permitan establecer una agenda tecnológica y de competitividad (plataforma tecnológica) para la adopción de un nuevo modelo sustentado en la innovación y el desarrollo tecnológico. Son variadas las experiencias a nivel mundial del papel que juega la generación de tecnologías, no solamente desde el ámbito privado sino público para la mejora competitiva en el sector astillero. En la región Caribe, gracias a la trayectoria de COTECMAR, podrían orientarse algunas de sus capacidades para definir de un lado la estrategia de mediano y largo plazo para el sector astillero, de otro establecer un centro de inteligencia de mercados y tecnologías y finalmente definirse como un animador entre los diferentes actores públicos y privados que conlleven al desarrollo de importantes proyectos de tecnologías sustentado en novedosos procesos de transferencia y comercialización, sin perder su misión de ser garante de la Seguridad y Defensa Nacional.

Palabras claves: Astilleros; clúster; aglomeración; plataforma tecnológica.

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Introduction

The national industry that supports the maritime transport services sector in the Caribbean region has been evolving dynamically in recent years. On the one hand, the sector is being recognized as part of national and regional public policy. The actors that take part recognize their potential in terms of productivity and competitiveness. Likewise, the agents that guide regional development consider it as a strategic sector for economic and regional development. In this way, and bearing in mind that the maritime sector has had an evolutionary trajectory in the Caribbean region due to its close link to maritime and port activities, it is considered a viable alternative to guide collaborative and integrating strategies through agglomeration schemes (cluster).

Like much of the country's regional initiatives, the Caribbean region and its productive activity move between two simultaneous but converging forces: Globalization-Productive Specialization and Regionalization-Innovation. The first, in the framework of the maritime industry and port, the "ship building sector", particularly in the Caribbean region, has been gaining a leading role. It is part of the sectors of the policy of productive transformation that led by the Ministry of Industry, Trade and Tourism, sustained in the National Policy of Competitiveness in promotion of the productive transformation defined in world class sectors *(DNP, 2008)*[1]; and in the National Policy on Science, Technology and Innovation; *(DNP, 2009)*. The second, the Caribbean Region and particularly the city of Cartagena and the Department of the Atlantic, they chose the maritime industry as a regional bet that aims to promote the productive apparatus articulating policy instruments of a regional nature especially in terms of Science, Technology and Innovation.

This article is intended to expose some guidelines on agglomeration schemes from international referents oriented by institutional arrangements at the local level or under regional schemes derived from public policies. For the definition of an animation model that integrates knowledge networks and the definition of the Cluster, some of the conditions in terms of scientific and technological capacities to be identified are the guidelines embodied in the research agendas and the presence of COTECMAR at the regional level. Priority elements justifying an intervention to propose an induced system of agglomeration and collaborative work at local and territorial level in accordance with the region's productive structure.

The strategic orientation of the shipyard sector must go through a strategic plan of organization and institutional arrangements, which lead to the creation of agglomeration schemes based on R + D + I activities, where the State has a decisive role when it comes to concreting incentives. The application of these "incentives" leads to the realization of the orientation, making the cyclical and structural determinants of the maritime and port industry visible. It also induces the recognition of cooperation schemes supported in the relationships and scientific and technological capacities as an instrument to support technological innovation of the shipyard sector in the Caribbean region. Its origin, the role of the agents, companies and institutions that make it up; and how the concept of knowledge management is incorporated is highlighted.

The first part of the text describes some conceptual aspects on the basis of the agglomeration schemes and some actions that guide the innovation (achieving better levels of productivity and competitiveness) and innovative means for the regional development. The second part describes the scope and limits of the shipyard sector's agglomeration scheme within the framework of the naval industry of the Caribbean region. and finally, without, without prejudice to other evidence, some paths are defined to consider the technological platform of the shipyard sector of the Caribbean region to promote development from innovation management models.

Conceptual Aspects

Recently, the country has entered into the public policy debate on the desirability of

[1] National Planning Department, Conpes Document 3527, *National Competitiveness and Productivity policy*, Bogotá June 2008.

driving economic regional development from the participation of actors at the local level. This discussion, which starts in large part due to the promotion of the productive bets and competitive strategies (Internal Agenda for Productivity and Competitiveness-DNP 2008-) and that has been gathering strength in the framework of the national policy on productive development and the guidelines of the national policy of Science Technology and Innovation in the country.

A greater self-determination in the decisions of the actors (companies and universities) located in certain territories and with influence in local agencies (e.g. chambers of commerce, municipalities, guilds and associations among others) starts by recognizing agglomerated productive structures that beyond their spatial location, seek to orient and create schemes for cooperation and knowledge management for economic and social development, improvements in productivity and competitiveness of the actors that are part of the productive systems.

The study of the phenomena of agglomeration and location of productive activities has a great theoretical tradition that is based on the pioneering works of the classical economy from the division of labor and the configuration of the territories. Marshall (1890), who begins with the division of labor as a condition of relationships between companies and the conception of a territory where these relations are developed in a context of interaction and learning. Coase (1937 and 1988)[2] realizes the significance of the vertical integration processes in defining the links that are derived in the relationships between agents and that explain the transaction costs to support the neo-institutional framework of the nature of the company. In the eighties a series of literature appeared to understand the relationships and connections between the agents in different productive systems and the reasons for the coexistence of the actors.

Michel Wear, in the year 1991, advanced with the concept of clusters (Saba 2003) and evaluated the management conditions of the industrial districts, (Texerira and Ferraro, 2009) address the relations and management schemes in value chains. In the framework of the competitiveness policies of several European countries, expressions like the competitiveness and innovation poles associated with a sector in a certain territory appear. These approaches, notwithstanding their different approaches from the degrees of development and participation of different actors, they share some features such as knowledge management and collective learning.

An agglomeration scheme (cluster) is the recognition of different actors with common characteristics in certain productive systems (static and dynamic links), with cultural and family relations, located in certain territories. Some of these agglomeration schemes have been induced by congruence in the public and private institutional relations that have been able to create spaces that identifies them as efficient and competitive productive structures. Therefore, a cluster (a grouping) facilitates the generation and dissemination of knowledge that is both tacit and explicit expressed in transfer and appropriation processes, which determine decisions or strategic actions.

A cluster, according to Michael Porter (1998), is a geographic concentration of interconnected companies, specialized suppliers, service providers, companies in related industries, and partner institutions in competing private fields but they also cooperate. According to Porter, the success of a cluster includes the organization of factors based on the conditions associated with four elements: demand, production factors, development and competition strategies and to the development of complementary industries. These groupings seek to obtain advantages such as:

- Better dissemination of information and a reduction in costs related to the coordination of agents.
- Increased productivity of cluster-owned enterprises.
- An innovation boost.
- Stimulus for the creation of new companies in the subject matter of the cluster (logistics, aerospace, automotive, etc.).

[2] In Willianson O and Signey G. Winter. The nature of the company. Origin, evolution and development. Economic Culture Fund. Mexico 1996.

At present the configuration of the different agglomeration (cluster) initiatives are based on the role that the management of scientific and technological knowledge plays. In this context it becomes important how knowledge is created and used; and how individual and group capacities are developed to generate, disseminate and use it. Empirical evidence of the relationship between technological development and economic growth is growing every day, as is the importance of technology as engine of the innovation in construction and improvement of regional competitiveness based on a greater cohesion of local actors.

An agglomeration figure comprising R + D + I activities for productive strengthening is based on the conception of the national innovation systems studied throughout history by Freeman (1997)[3] as a network of public and private institutions whose activities and interactions initiate, import, modify and disseminate new technologies and that are driven by economic and social policies. Lundvall (2005)[4] considers a national innovation system as a set of elements and relationships that interact in the production, dissemination and use of new and useful knowledge for its economic leverage, located in a specific region. Metcalfe, (1995)[5] emphasizes the nature of this interaction by considering that this contributes to the development and diffusion of new technologies, context in which, the intervention of the State is required in designing and executing policies that stimulate the processes of innovation.

The cluster initiatives based on innovation and cooperation as *Key* elements means having a critical concentration of resources in a geographical place, where collaboration is prevalent from three types of actors: companies, universities and regional/local authorities. The State (represented in the regional agencies) establishes environment conditions that guarantee and facilitate the actions of the productive sector. Thus, it will be possible to encourage and promote the use of the knowledge generated by the scientific research in the productive processes, to channel financial resources for the development of the scientific and technological infrastructure, to orient the efforts for the productive improvement, especially in favour of added value and innovative capacity, all to achieve competitive conditions in the market.

It should be noted that cluster initiatives based on activities of research, development and innovation are based on the novel concept of open innovation, proposed by Henry Chesbrough (2003)[6] to promote relationships to maximize the generation of knowledge, information, capacities and skills in collaborative schemes. This concept goes against traditional schemes of innovation (closed), propitiated by departments of R&D of companies according to their own capacities, knowledge and schemes. Open innovation allows to capacities and knowledge to be optimized and has the potential to accelerate work dynamics, the understanding of joint needs and the distribution of ownership for the obtained developments.

Much of the development of industrialized countries in the last 30 years is explained by the close relationship between scientific and technological research and innovation. The majority of the transformations of the most advanced productive structures are recognized by the capacity of generation and appropriation of knowledge of companies, thanks to the development of the policies of science, technology and innovation, in creating spaces to encourage work in a network among researchers and entrepreneurs. The generation of new knowledge that allows innovation and technological development are effective tools in the creation of regional competitive advantages (Innovación Europea 1995)[7].

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[3] Freeman C and Luc Soete *National System of Innovation*. The economics of industrial Innovation Third Edition 1997- The MIT Press.

[4] National Innovation Systems - *Analytical Concept and Development Tool* by Bengt-Åke Lundvall 2005. Paper presented at the DRUID-conference in Copenhagen June 27- June 29, 2005.

[5] Metcalfe, J. S. (1995). The economic foundations of technology policy: equilibrium and evolutionary perspectives. In P. Stoneman (Ed.), Handbook of the Economics of Innovations and Technological Change. Oxford: Blackwell Publishers.

[6] Chesbrough (2003), The Era of Open Innovation. Spring MIT Sloan Management Review.

[7] Innovación Europea (“European Innovation”) (1995), More research and innovation. Investing for growth: a Common approach. European Commission, Brussels Belgium.

In the development of agglomeration strategies (Cluster), there is a wide variety of sources and actors generating knowledge. In companies there are R&D units, groups, specialized departments of quality, design and marketing. In its environment, business initiatives are supported by public entities, R&D centers, universities, technological development centers, research and excellence centers, consumers, etc. Notwithstanding the wide variety of sources and actors, successful countries are characterized by channeling major public resources through regional (local) science, technology and innovation systems that have led to the development of long-term strategies and with a competitive and market guidance. A demonstration are the regional innovation poles that guide their efforts in key sectors (strategic or export oriented) for competitiveness in the framework of the regional initiatives driven by the European Union (Innovación Europea, 2006 and 2007).

A successful approximation of agglomeration schemas are the successful practices that have been consolidated globally in the territorial development represented by the Italian industrial districts, or the agglomeration schemes of Silicone Valley and the Triangle Park in the United States, Glenn Valley in Scotland, the Inshu park in Taiwan, etc., and in the schemes encouraged by recent European policies to consolidate competitiveness poles and innovation.

Scope and limits of the agglomeration scheme of the shipyard sector that supports the naval industry

The Regional Competitiveness Plan of Cartagena and Bolívar (2008-2032) –PRCCB 2010- contemplates the design, construction and repair industry of ships as a driver of the local economy[8]. In this way it defines as a strategic objective to "internationally consolidate the naval, maritime and fluvial cluster of Cartagena and Bolívar aimed at providing technology solutions integrated to the design, construction and repair industry of boats", where the internationalization of this sector is projected and the consolidation of a cluster with great potential that would allow the economic development of the Caribbean region.

Starting from the recognition of the actors who are part of the maritime and fluvial industry, agglomeration initiatives have been configured to strengthen the productive development of the ship yard sector in the Caribbean region led by the PTP of MICT and the impulse that has been given to the services that support the nautical cluster: Nautical Cartagena[9]. This approach aims to promote in regional actors the management and strengthening of links that promote collaborative strategies aimed at developing new changes, promoting research, development, innovation and stimulating the entrepreneurship of new technology-based companies.

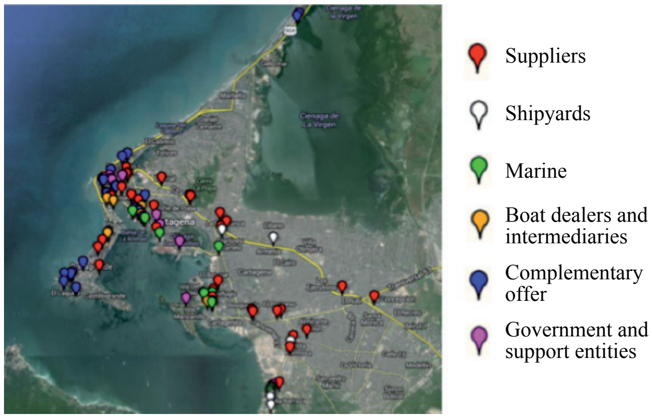
Setting the limits of the cluster is not an easy task and usually requires a process of animation and definition to determine the relations and links of complementarity between the sectors and institutions to participate. From the definition of the cluster of the shipyard sector we pass to recognize the maritime transport sector and the port environment where a set of activities are performed with different actors. Activities include business, industrial and logistics activities, among the sea and nautical transport customers: the cargo of merchandise, passengers, and all the agents of the zone of influence of the ports, the free zones and the maritime enclaves as well as the new development of marinas.

Specifically, as defined by the PRCCB 2010, Cartagena has an excellent geographical position, natural conditions of depth and protection of

[8] Regional Competitiveness Commission of Cartagena and Bolívar. (2010). Regional competitiveness Plan Cartagena and Bolívar 2008 – 2032.

[9] The Cartagena nautical cluster includes companies dedicated to the production of boats (emphasize that production is marginal), particularly fiber boats with outboard motor with a maximum length of 6-8 meters, supplying nautical accessories such as outboard motors, electro-electronic equipment, metalworking parts and structures, painting, among others, and equipment for nautical sports activities (diving, Kitesurfing, windsurfing, kayaking, etc.); As well as the management and development of marinas., dry marinas and MAVs (Marina-Shipyard-Varadero), including services to the boat (mooring, storage, fuel load, repair and minor maintenance). There is also an important offer of complementary tourist services such as lodging, food, commerce, among others. Competitiveness, Nautical Cartagena: Competitive route of the nautical Industry 2015

Fig. 1. Cluster Map in Cartagena



the bay, human resources that are qualified and trained for the care of vessels up to 600 tonnes, an adequate infrastructure and canal of 3,600 tons per boat. In 2016 the shipyard sector that is part of the cluster had more than 70 actors that are part of the shipyard sector, 85% of the ship building activity is located in Cartagena with more than 3000 workers. Cartagena is recognized for its military and commercial shipyards, highlighting the leading role of Cotecmar at the forefront of research and development activities[10].

On the other hand, as shown in Competitiveness 2015, Cartagena is one of the ports with the greatest historical weight of the Caribbean. It is the most important port in Colombia in the area of container loading and also in cruise tourism, which means it has a naval and nautical vocation. In Cartagena nautical tourism has witnessed a notable development, and in the bay area there are several facilities for recreational boats, which have joined shipyards located in other parts of the city, such as in Albornoz and el Bosque, complementing the offer of services required by boat owners, such as yachts and sailboats (See Fig. 1).

Like the corporate management models, the coherence of decisions and actions taken by the different cluster actors are essential to establishing common strategic guidelines and sharing performance criteria. What's more, the guidelines, plans, which currently orient the shipyard sector cluster have to be developed around a specific purpose, be it of broad connotations like the development with the maritime and naval industry, or a specific geographical area (the city of Cartagena and the Department of Atlántico and Bolívar for example) or more focused like the solution of a technical problem such as the support services to the naval and port industry through the shipyard sector.

It is necessary to define the scope and limits of an agglomeration scheme for the shipyard sector within the framework of the maritime transport sector and the naval industry , where actors are identified that have characteristics and particularities that must be taken into account in order to achieve certain development and growth objectives in the short and medium term, as established by Ospina (2016)[11] based on what is defined by Untcad 2015 as follows:

- Maritime transport plays a crucial role in defining the benefits that ships must develop as it identifies those improvements and innovations that will need to be implemented in ships and artifacts, in order to be able to improve the processes of design, construction, operation and logistics management.

- The infrastructure, port management activity and port services are major sectors in the

[10] Regional Competitiveness Commission of Cartagena and Bolívar. (2010). Page 36.

[11] Ospina, Juan C, Ideas for a reflection on maritime transport in Colombia, in La Timona magazine No 25 June 2016.

transport logistics chain, key elements for intermodality and consequent promotion of maritime transport as an alternative or complementarity to other types of transport.

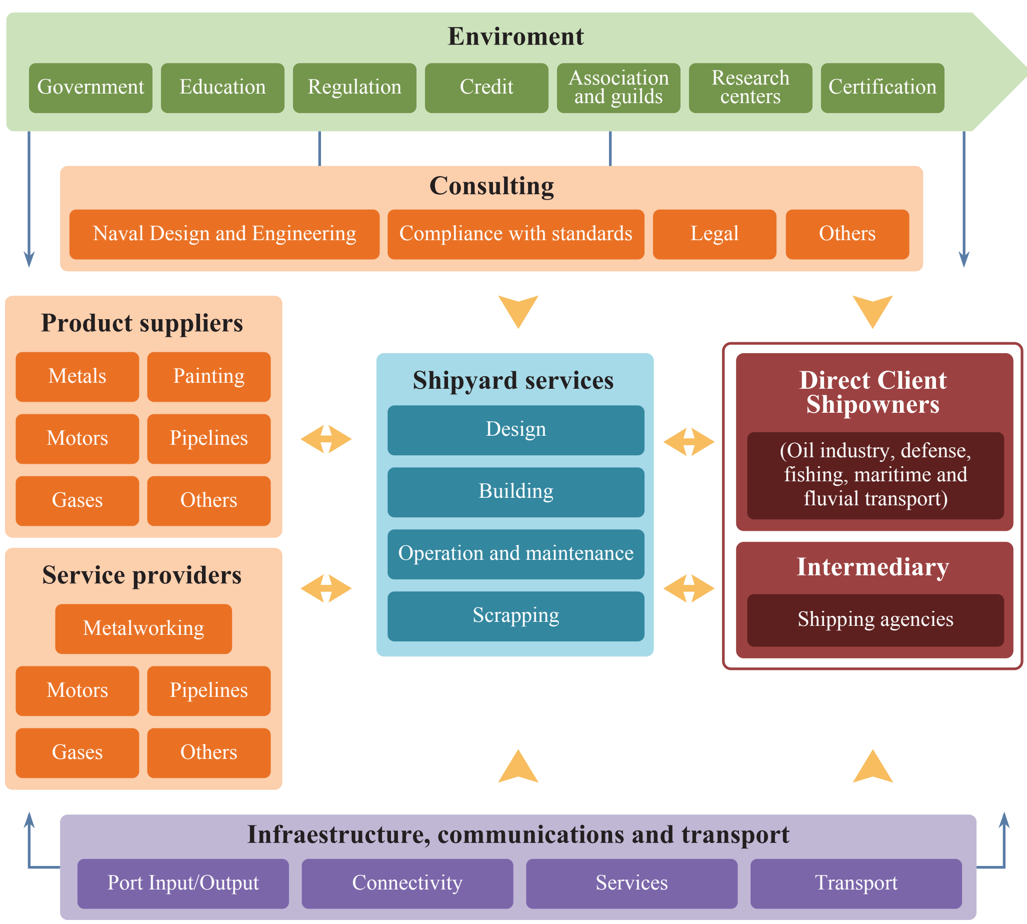
- The Exploitation of marine resources through platforms or artifacts dedicated to the exploitation of mineral resources, hydrocarbons and fisheries, aquaculture and other resources of the sea, is an element essential for obtaining these resources from diversified origins in relation to their traditional sources. In addition it involves production in water away from the coast, that are ultra-deep or in arctic regions.

- The design, construction, transformation and repair of all types of ships, Naval platforms and artifacts, including off-shore industry and nautical and recreational needs, they need to respond to the ever more complex demand for ships that are more sophisticated, more secure and more respectful of the environment and that require, therefore, a more developed technology; and all of this with lower operating and maintenance costs.

- The activities of the auxiliary industry and services have an increasing importance in the total value of the vessel, and may even reach three quarters of the final value. The number of companies with national capital that compete successfully in this sector with their own technologies in an open and truly globalized international market is remarkable, offering its customers the solutions that allow them to respond to the demand of technologically innovative vessels.

Particularly as defined by the MINCIT the shipyard cluster sector includes activities oriented

Fig. 2. Map of Actors - Shipyard Sector Cluster



to the services of repair and construction of boats in an integrated way with the maritime and port industry located in the Caribbean region. This is illustrated by the map of actors defined by the PTP-MINCIT.

Thus, a broad definition of a maritime cluster would also include logistical and transport activities[12], for the case of the cluster of the shipyards sector in the Caribbean region it would be:

The shipyards, will be the axis, which includes the companies that build and repair ships (with steel and other materials such as wood) of very diverse types and tonnages, for the transport of goods and passengers or for military use.

Suppliers of inputs and services: companies dedicated to the supply of equipment and naval services that include:

- Companies whose activity is aimed at providing service to shipyards, such as submarine work, enabling, integral services, welding, boiler making, scaffolding, paint applicators, assemblies, cleaning, anti-corrosion protection, electronics, electricity, etc.

- Also included are design companies of boats and engineering (Mechanics, electronics, surface treatment) and technical offices.

- Companies whose activity is focused on the provision of the equipment that make up the engine room of a ship. It is usually divided into 2 main groups:
  - Engines
  - Auxiliary equipment of machines: Pumps, alternators, advanced systems of diesel-Electrical propulsion, electrical and control panels, cooling and ventilation, insulation, valves, onboard automation systems, electronics, electricity, etc.
  - Supply of artifacts for the hull or deck of ships, such as cables, pipes, chains, electronics, electricity, insulation, hydraulics, structural elements, hoisting equipment, capstans, etc.

- In the nautical activity, companies that offer the service of design, construction, sale/distribution and repair of different products are recognized. Equipment and materials: related more to the equipment of the boats such as: engines, transmissions or communication mechanisms, parts of the boat, masts, rafts, emergency signals, electromechanical mechanisms, painting, resins, wood, carpentry, etc., as well as the supply of accessories: holsters, nets, log clocks, ropes, life jackets, and other boat accessories.

- Other companies that offer inputs such as: Oils, fuels, and the whole range of detergents and cleaners, etc.

Of a technological platform towards an agglomeration of the shipyard sector

The National Policy of Science, Technology and Innovation, expresses the need to strengthen and design new instruments, by strengthening innovation and productivity in companies and organizations, with the aim of ensuring in the long term the competitiveness of national and regional production goods and services; and to improve the living conditions of the Colombian population (DNP-2009)[13].

These new conditions of the economic environment, together with the greater requirements of the global consumers and the new ways of doing business, impose on the companies the challenge of modernizing their organizational structure and, even more so, to innovate in their processes, products, goods and/or services, their offer of value and their business model, all for the purpose of achieving greater competitiveness. The

[12] From the definition defined by Valdaliso Gago [et al.]. The historical origins of the maritime industry cluster in the Basque Country and its legacy for the present/Jesus-Donostia: Eusko Ikaskuntza; Orkestra. Basque Institute of Competitiveness, 2010 Pages 72 and 73.

[13] National Planning Department. *National policy on science, technology and innovation*. Document Conpes No. 3582. Bogotá, April 2009.

modernization and business innovation process is complex because it not only obeys the internal conditions of each company, but also the conditions of their economic and social environment, and the close relationship between the capacities of the companies and those associated with local scientific and technological capacities.

In the country, there is a belief that the agglomeration schemes (cluster) *per se* are beneficial for innovation and local development. In reality experience has shown that very little is known about what they mean and really of how they operate. There is a tendency to implement policies to support the clusters without defining actors and limiting the actions and roles. many of the initiatives are not defined as such and usually support policies and promotion to the cluster are confused with the instruments of the national public policies of productive development and innovation. The support instruments for the clusters, are usually not very novel, but what is new is the form of the combination of instruments that is chosen and appropriate by direct actors. Therefore, the challenge that is posed to the local actors is to find the ideal combination of tools.

The local and regional authorities should have the best conditions to adopt the support policies for the cluster given its proximity to the companies. A directed cluster support policy is not possible and even less so if management is oriented using the generic instruments defined by the government entities. A good identification of the relationships of the clusters contributes to the elimination of administrative barriers (red tape) that usually limit public aid. A cluster needs some type of geographical settlement, proximity is essential, despite the progress of communications, this is necessary to guarantee the transfer and appropriation of knowledge that supports the degree of local innovation.

A *successful cluster* is that which defines a long-term vision and that is driven by entities with charismatic people. It's easier to start with a small set of actors with matching actions. An alternative to enable the cluster is the definition of a territorial brand to identify the region with a particular industry or a group of products. Typically, brands that are designed by local administrations, in many cases do not have any repercussions, many times they are good purposes without transcendence. When the productive and academic sectors are backed and supported by local administrations when defining a brand, it can be very beneficial for the companies, the promotion of investment, marketing of products and especially to the region where they are located.

What does an agglomeration scheme mean from an institutional point of view at the Caribbean Region 1 level? Are there basic input conditions for configuring a cluster based on innovation and cooperation for the industry of shipyards? It is a fact that for the Caribbean region, it is a priority to orient the scientific, technological and institutional support capacities according to the needs defined by the initiatives of the productive and competitive commitments made at the regional level, in this case given the increasing importance of the naval, maritime and fluvial industry of the Caribbean region and of actors such as the universities and Cotecmar that have shown consistency and vision by supporting initiatives of regional technological development .

The maritime and fluvial industry in the Caribbean region and, in general, the actors related to maritime activities and the different aquatic waterways, are characterized by being immersed in strong global competition demanded by the international trade in goods (cargo) and services (nautical tourism in its different expressions). A communal bet made through a Technological Platform for the Shipyard Sector Cluster – PTCSA- focused on the priorities required by maritime activity today, from a medium-and long-term perspective, must provide competitive tools and the basis of know-how, enabling all actors to successfully respond to the challenges of globalization.

The set of actions identified above to boost a cluster of the shipyard sector in the Caribbean region requires the definition of the development of technologies in line with the needs of the productive sector in order to improve productivity and regional competitiveness. Basically what happens is that, given the central importance of technology as an instrument to achieve competitiveness, it is necessary to define actions in terms of the science and technology policy for and depending on regional development (Ondategui 1999)[14] that is focused on improving the links between actors, collaborative capacities and the development of technologies that promote innovation of the Naval, Maritime and fluvial industries In this way the cluster initiative of the shipyard sector of the Caribbean region begins by defining a number of stylized facts that leads it to be profiled as an alternative of regional innovation, based on relationships and of Knowledge management, among which the following are considered:

- To define and develop a Technology Platform for the shipyard sector cluster – PTCSA of the Caribbean region defined with time limits. It is part of a *Planning process*, defined by a strategy with medium and long term vision, supported by research and technological development programs, responding to business needs characterized by their exposure to the global market and with the concurrence of many companies of different types of technologies.

- To design a specialized services platform for the promotion of cluster innovation. Considered a *Business model*, whereby from a technological productive limitation a technological solution can be offered. This model should be based on the current capacities of the groups and research centers belonging to the regional universities and COTECMAR. Therefore, services must be offered ranging from formulation, management, research, technology transfer at different levels and areas of knowledge, supported in research and development processes.

- Promote network knowledge management. The cluster must be part of a *network of public and private institutions* belonging to the Regional System of Science, Technology and Innovation that act as managers of projects, providing novel instruments to guide and strengthen research and technological development processes, and whose fundamental purpose is its performance with the productive sector.

- To promote a Regional Innovation model. The promoting of regional innovation should take advantage of recognizing the cluster of the shipyard sector of the Caribbean region, starting from the definition of a brand. The model should perform activities of animation, articulation, cooperation between the different actors within the cluster and related actors at the local, national and international levels, to develop programs and projects to support the technological conditions and characteristics of the region itself

- Provide innovative means to the productive sector. The Caribbean region must develop infrastructure to improve the scientific and technological capacities to promote the scientific spirit, the ability innovate and entrepreneurship. The internal evidence shows the creation of Science and Technology Parks, technological development centers, research centers, the network of laboratories, among others, that support the generation of new products, but that especially count on business support services for the promotion of innovation

- To promote the investment of public-private resources in R&D. Have a *Scheme of Public-Private funding* for the development of the activities of applied research as a manifestation of the commitment of the different public and private actors in advancing the technological development and knowledge management.

In a general manner and to advance the development of the activities, the Cluster actors, within the framework of the PTP, should continue to guide their actions through an institutional structure with scientific and technological capacities, articulation and coordination schemes. Notwithstanding the above, and taking advantage of the trajectory of Cotecmar, a Technology Platform for the Shipyard Sector cluster – PTCSA- should be proposed that includes a common agenda to strengthen and

[14] Ondategui, Julius Caesar. *Innovation and Regional development networks in the Northwest Peninsular*. Regional Studies Magazine, Universidad Complutense de Madrid. Madrid Spain 1999

promote innovation[15]. To do this, the following is required: i) To define a vision of the shipyard sector in the medium and long term and its valuation in a consensual way. ii) Determine quantifiable and measurable objectives. iii) Define actions to be undertaken to achieve these objectives. iv) Determine the priority activities of R + D + I by the group of stakeholders in the shipyards sector and related industries. v) Define the objectives to be achieved by mobilizing the necessary human and financial resources.

In this way, the cluster created is presented as a new paradigm in the ways of producing and organizing according to regional knowledge. The probability of achieving this will be greater for those who understand and adopt creatively and intelligently the notion of technological innovation as a guide to competitiveness, which has generated in recent years a change in the business culture, with the deliberate and systematic incorporation of technological management as a dominant dimension in the modern management of organizations.

As part of the development of the Technology Platform that should support the cluster of the shipyards sector, it is considered to work in some specific areas for each care sector, supported by the extensive human, scientific and infrastructural capital that facilitates the linkage of investigative processes to the needs of the different actors and producers of the maritime and naval industry of the Caribbean region. In this way, the orientation for the construction of the Technology Platform for the shipyard Sector cluster – PTCSA as an alliance for innovation, should guide the productive development that supports the maritime and fluvial industry in the Caribbean region.

By way of conclusion a final reflection

Today, science, technology and innovation are strategic factors that explain the generation of value added and competitiveness of countries, regions and companies. In this new scenario, the generating factor of wealth and human development, is based on the capacity of people and companies to develop products, goods, services and processes in general that are innovative, and that allow to practical applications to be developed based on the generation of knowledge derived from the processes of research, technological development and innovation.

The probability of having a maritime and naval industry as a world class sector world from the impulse of the development of the cluster of the shipyard sector, exposed to globalization necessarily must define a consensual innovation strategy that is animated by local actors of the Caribbean region. The proposal, such as the development of the experiences of European Technological platforms such as the Spanish Maritime Technological Platform 2020 "puts the agents in contact, brings together and facilitates the generation of relationships and multi-directional inter-actions to use the knowledge generated from research projects".

Therefore, in order to reach a consensus on the direction of strategies supported in the development of research projects the development of new necessary knowledge should be promoted to ensure compliance with the Regional Competitiveness Plan of Cartagena and Bolivar 2008 – 2032. The demand for effectiveness implies encouraging collaboration and cooperation in the R + D + i actions of all the agents involved, as well as, significantly increasing the financial and human resources devoted to such activities, from both private origin and public sources.

In practice, the above involves action from all the areas of policy: national, departmental and local, science, technology, and innovation; and from the partner entities, the actors in the productive sector, thinking about the regional development that allows interdependence relationships to be multiplied, and the fundamental establishing of stable information channels and creation of collaborative opportunities around specific problems.

[15] Developed from the Spanish Maritime Technological Platform 2020.

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Strategic planning and experience in the construction of the OPV Project for the Chilean Navy

Planificación estrategica experiencia en la construcción del Proyecto OPV para la Armada de Chile

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Abstract

ASMAR's shipbuilding policy indicates that this activity will be centered and dimensioned on primarily serving the requirements of the Chilean Navy and the State. The correct use of the information is fundamental in the evolution of the projects. By applying this knowledge and evaluation criteria to the strategy of the Naval Construction Management, it will contribute in future projects by improving the planning levels obtaining more detailed, efficient and effective results. Below we present the experience in the strategic planning for the construction of the OPV4 project, *Cabo Odger* ("Marine Lance Corporal Odger") for the Chilean Navy.

"We want all our shipping clients to recognize us as a serious shipyard, with dedicated commitment and technical quality, and we have used ingenuity and experience to solve problems that we have faced. However, we must not fall into the temptation to rest on our laurels, on the contrary, we have the obligation to continue on this path of commitment with our daily work, and to meet our deadlines" .

Today, shipbuilding is defined as a highly complex industry, that is highly competitive with elevated costs. The goal is to extract the most important contents and work with real, efficient and effective information, so that each construction process is not affected by external agents. There are three differentiating factors that make a shipyard more competitive and improve its production processes, resulting in a reduction of work time and, therefore, a reduction of costs; these are: the construction strategy, strategic planning and logistics. ASMAR has the technical and technological capacity to integrate various elements into its workshops in the stage prior to assembly. This process marks an important step between the construction strategy and the project planning.

Key words: Strategy, Planning, Logistics, Production.

Resumen

La política de construcción naval de ASMAR, indica que esta actividad estará centrada y dimensionada para atender prioritariamente los requerimientos de la Armada y del Estado de Chile. El correcto uso de la información es clave en la evolución de los proyectos, dicho conocimiento y criterios de evaluación fueron aplicados a la estrategia constructiva de la gerencia de Construcción Naval, la cual contribuirá en próximos proyectos a mejorar los niveles de planificación obteniendo como resultado niveles para producción más detallados, más eficientes y más eficaces. A continuación, se presenta la experiencia en la planificación estratégica para la construcción del proyecto OPV4, "Cabo Odger" para la Armada de Chile.

"Somos todos nosotros los que permitimos que nuestros clientes navieros nos reconozcan como un astillero serio, de compromiso y calidad técnica, habiendo utilizado muchas veces el ingenio y la experiencia para enfrentar y solucionar los problemas que se han enfrentado. Sin embargo, no debemos caer en la tentación de sentirnos cumplidos con lo que hacemos, por el contrario, tenemos la obligación de continuar en este camino de compromiso con nuestros trabajos diarios, sobre todo con el trabajo bien hecho a la primera y el cumplimiento de plazos".

Hoy en día, la construcción naval se define como una industria de síntesis, es decir, busca extraer los contenidos más importantes y trabajar con información verídica, eficiente y eficaz, de tal manera que cada proceso de construcción no se vean afectados por agentes externos. Existen tres factores diferenciadores que hacen a un astillero más competitivo y que mejoran sus procesos productivos, consiguen una reducción en sus tiempos de trabajo y por lo tanto, logran una reducción de costos, estos son; la estrategia constructiva, la planificación estratégica y la logística. ASMAR y su astillero constructor, posee la capacidad técnica y tecnológica de integrar en sus maestranzas diversos elementos en la etapa previa al montaje en grada, es justamente este proceso que marca un quiebre trascendental entre la estrategia constructiva y la planificación de un proyecto.

Palabras claves: Estrategia, planeación, logística, producción.

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Introduction

Shipbuilding is defined as a highly complex industry, that is very competitive with elevated costs *(Depto. de Información de la división de Productos Industriales y Tecnología, 2011)*. The goal is to extract the most important contents and work with real, efficient and effective information, so that each construction process is not affected by external agents.

There are three differentiating factors that make a shipyard more competitive and improve its production processes, resulting in a reduction of work time and, therefore, a reduction of costs; these are:

- The Construction Strategy (C.S.[1])
- Strategic Planning
- Logistics

ASMAR has the technical and technological capacity to integrate various elements into its workshops in the stage prior to assembly. This process marks an important step between the construction strategy and the project planning.

General Objective

The objective is to plan, elaborate and disseminate the different stages of the construction of naval artifacts and other items in an efficient manner.

Specific Objective

The Manual of Construction Strategy (C.S.M.[2]) is a production tool. It seeks to guide and deliver clear and relevant information on the construction of the different units of the Asmar shipyards.

Utility, benefits and importance

Construction Strategies can cover the most overarching aspects to the smallest details, but always with the purpose of delimiting the fundamental aspects of any project. Currently, due to the diversity of the administrative and productive processes, the administration of projects must be handled with clear and specific information. Poor management of this information can lead to errors in the correct development of a project, directly affecting the degree of progress of the different construction stages.

The Construction Strategy will include the general aspects of the shipyard, considering all the limitations present when creating the manual. However, it should be defined in a specific and individual way for each product to be built. Through the Construction Strategy Management it will be possible to plan, direct and control all the critical activities that affect the productive process of each unit, so it is important that this be defined from the initial phases of any shipbuilding project.

Use of information

The Construction Strategy Management is a document oriented to the delivery of real information to the different production workshops, which depend directly on the Shipbuilding management.

The correct use of this information is subject to the distribution of this document, of the adaptability and acceptance criteria by the shipbuilding management workshops, which is why this new stage begins by training the personnel directly involved in the Construction of the product. It will be important to carry out this introduction to the workshops, every time a new project is started, as each construction will have different ways to be approached. *(Traba & López, 2004/2006)*.

The Construction Strategy Management. is composed of the three main parts, they are:

Generalities

This section explains in a concise way the location of the product to be developed, in addition to a small introduction and additional content, covering the

[1] Construction Strategy.
[2] Construction Strategy Manual

position, space and personnel of the workshops of the naval construction management.

Assembly Sequences

This section details the assembly sequences of the different blocks, either at the structural level with the definition of the positioning of the pipes in a sequential and logical way, in addition to referring to the main equipment contained in the block, in order that the development of the construction of the unit is as harmonious as possible, so that it does not affect the planning of the project.

References

This part contains all the reference information that was used to prepare the manual, as well as a checklist of the different systems identified with the FORAN®[3] nomenclature. The latter is so that supervisors and workshop engineers are able to quickly identify and isolate systems, bases or equipment, according to requirements.

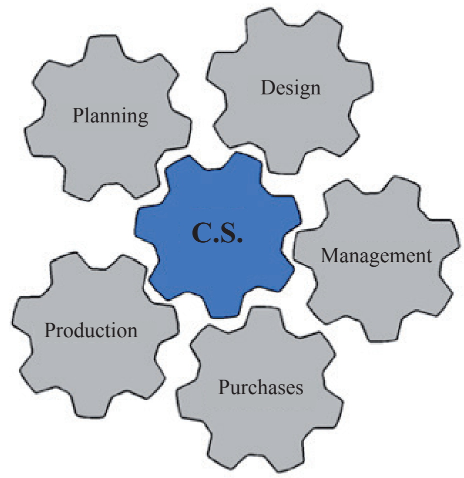
Differential Aspects

The Construction Strategy section was created in May 2009 with the objective of establishing the methodology for developing, disseminating and updating the Construction Strategy of shipbuilding projects. This was applied directly and transferred to the Construction Strategy manuals, which were elaborated at the area level. The distribution of these manuals to the workshops was only through the registration in the computer network of the shipyard, which meant that one of its main objectives, to disseminate the information, was not complied with.

The new methodology proposed by the Construction Strategy Management, has the same objective established by the Construction Strategy section since its creation, nevertheless there is a significant change in the information embodied in the new manuals.

With this approach the goal is for the Construction Strategy to mobilize all the activities of the program and be the main actor in decision making in the project and production. (Fig. 1)

Fig. 1.



In this new version of the Construction Strategy it was decided to work at the block level, which means to change the information horizon, going from macro to micro format. This new Construction Strategy will have a greater level of construction details with the aim of facilitating and improving the planning and the release of the works to the shipyard workshops.

Evaluating criteria

In view of the different specific objectives determined by Construction Strategy and for the expected learnings, the evaluation criteria are proposed and, from them, questions are suggested and prepared so that the Naval Construction workshops can evaluate the manuals and give us guidelines for our continuous improvement. It should be noted and remembered that the main objective of these Construction Strategy manuals is to meet the needs of our customers, the project and the production of the shipyard.
The criteria indicated are:

- TO VERIFY to what extent the workshops have internalized the concepts and proposals

[3] CAD/CAM system, 3D modeling, SENER Company

of the Construction Strategy Management
- TO OBSERVE how workers implement the concepts of the main and secondary actions proposed in the Construction Strategy Management
- DETERMINING the degree of adoption and internalization by production personnel with respect to the proposals of the Construction Strategy Management

Management of materials and production planning

From the perspective of the optimization of decision making, a production plan must balance the fulfillment of three commonly conflicting objectives: Increasing the satisfaction of demand, reducing inventory levels and maximizing production efficiency (reducing the time and cost of set-up). These objectives are mainly associated, but not exclusively so, to the priorities of the commercial, financial and production areas, respectively.

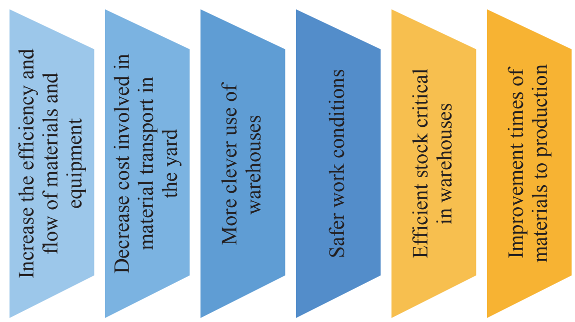
The materials management systems of the different construction processes ensure that the materials and products are available in the correct amount and at the time required for the shipyard and the project. There are several methods of materials management. The best system for long-term projects, such as shipbuilding, is the MRP[4] system (Fig. 2), which operates on the basis of material requirements planning and operates with a "push" [5]system philosophy. The components must be supplied before being required by the different shipbuilding workshops (Fig. 3)

Planning Levels for Production

The planning basically consists of the previous analysis of the requirements of the client that are all proposed in the high level requirements. Each of the works are structured in different stages, the estimation, analysis for the technical feasibility, terms and resources, and the programming is

Fig. 2. Asmar MRP System, OMEGA

Fig. 3. MRP System benefits, OMEGA



added to them at different levels: Level 1, Level 2, and Level 3. (Fig. 4).

Within the Construction Strategy of each ship, it is necessary to establish objectives that can be controlled, such as indicators of productivity and management of the various production processes.

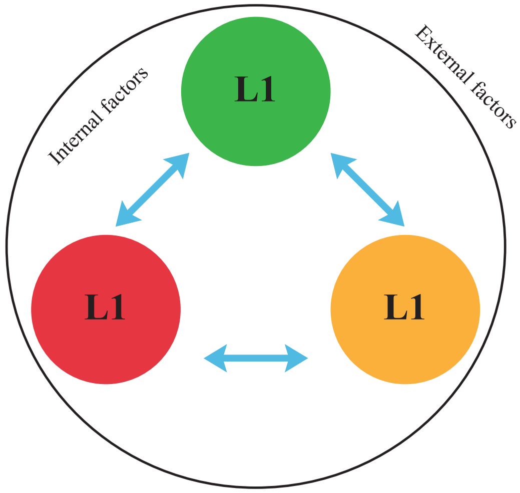
The main objective of these indicators is to be able to provide the organization with a tool that allows a better control of the productive process, and therefore, better planning, in addition to knowing, through the periodic analysis of these indicators, the degree of effectiveness achieved for each construction.

Level 1

Program that contains the most important activities of a project. The program is based on a preliminary evaluation of the project and is structured for decision-making by senior management.

4 Materials Requirement Planning
5 Planned Management System

Fig. 4. Systemic planning diagram



Level 2

Program that contains the activities of the main structure at block level, the team activities at the specialty level, together with the systems and areas to be executed during a project, which is the reference for the third level planning process. Level 2 contains the tasks of the project, is directed at the operational level and as support to production managers, who use it to manage their execution and to coordinate the productive centers that interact in the project.

Level 3

Program in which the tasks of Level 2 are detailed. Level 3 is aimed at the operator (Shipmasters, Production Engineers, etc.), for the coordination of the activities involved in the execution of the works. This program is prepared by the Production Department in coordination with the production management for highly complex jobs.

Due to the different objectives determined by the Construction Strategy specialty it is necessary that Level 3 planning includes the proposals included in the Construction Strategy Management, as it shows the good results obtained in the development of the Construction of the OPV *Cabo Odger* ("Marine Lance Corporal Odger"). It is important to mention that this project implements the use of a Construction Strategy with this level of referencing and details allowing a more efficient construction.

Level 3 Modified according to the Construction Strategy Manuals

Strategic Planning is a management tool that contributes to decision making in the organizations focused on the current task and the path to follow in the future to adapt to the changes and the demands imposed on them by the environment so as to achieve the maximum efficiency and quality of the goods and services provided.

In each project a more detailed programming of the activities and workshops is necessary, in order to fulfill the objectives established by the organization and the project.

Intervention at the current level 3 of production is the beginning of this change, since it allows shipbuilding workshops to improve planning levels, save resources by allocated task, improves the sending of information towards the work fronts, improves the communication of process engineers, the shipbuilding logistics unit, the design department and the Construction Strategy area.

This intervention seeks to organize information by generating an efficient distribution of the workshops and establishing a level 3 according to the requirements of the Construction Strategy, the project and the organization.

Benefits of the Construction Strategy

There is a variety of literature on the benefits of implementing the Construction Strategy within a shipyard; however, this is not exclusive to companies in this area, as it can be applied to other companies or manufacturing industries.

The correct uses of this tool brings multiple contributions to the project management and planning. The ASMAR Shipyard gained experience through the construction of the OPV 4 project

Cabo Odger ("Marine Lance Corporal Odger") for the Chilean Navy and the following benefits stand out:

Materials Management

- Supply of materials according to the plan.
- Efficient management of critical stock.
- Reduced inventory costs.
- Optimization of spaces and storage times.

Planning

- Maximize and improve demand compliance.
- More detailed planning levels.
- Efficiency in critical equipment warranty times.

Production

- Supply production requirements efficiently
- Maximize productive efficiency.
- Reduction of the times to dispatch information to the work fronts.
- Ordering the dispatch of information to the workshops.
- Reduction of the accident rate.
- Improvement in the ergonomics in the execution of the works in the workshops.

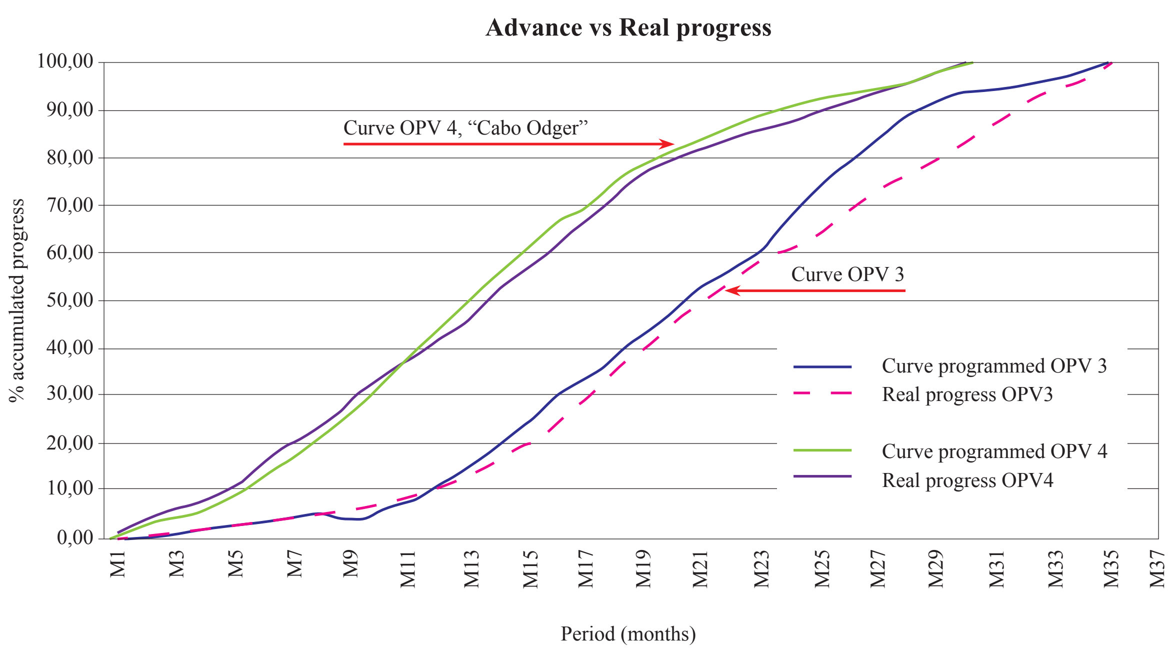
Fig. 5, represents the difference (in the same months) between the projected advances vs. the scheduled time of the projects OPV3 and OPV4 *Cabo Odger* ("Marine Lance Corporal Odger") with the latter still in progress.

Although ASMAR has already had experiences with similar projects (OPV 1 and 2), there is evidence that the efficient implementation of strategic planning and the use of knowledge management, specifically the use of the "Construction Strategy Management" tool in the OPV4 project, will contribute to cost savings and meeting final delivery deadlines.

Conclusions

While making good strategic decisions is one of the organization's major responsibilities, the entire productive chain must be involved in formulating, implementing and evaluating strategies. Participation is essential in order to make sure that all areas are commitment to the required changes.

Fig. 5. Comparative graph between projects OPV3 & Project OPV Cabo Odger ("Marine Lance Corporal Odger")



The inclusion of this Construction Strategy throughout the logistics and production chain must involve the entire organization of shipbuilding management and its dependent centers, as the participation of just one center can generate unexpected results.

The Construction Strategy has to look at everything. Through the personnel and the different tools it has available it is able to carry out the sequencing and logical integration of the works in different stages of assembly of the unit under construction.

It allows the development of pre-operation equipment at the panel level, proposing criteria for the assembly of these elements, with the aim of minimizing interference between the different workshops of the production department.

Clear evidence of a decrease in the programming time, and a greater efficiency in the processing of tasks by the dispatcher to the different productive fronts has been displayed.

A decrease in hot work has been achieved by avoiding redoing welding in finished spaces and reducing the risk of accidents to our collaborators.

The decentralization of the administration in the tasks and responsibilities in the project can be achieved as a consequence of the implementation of the knowledge management and the correct use of the information of the three axes or differentiating factors:

- The Construction Strategy
- Strategic Planning
- Logistics

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Prospective platform for the improvement of the competitiveness of the Colombian shipyard sector through the development of integrated logistical capacities

Plataforma prospectiva para el mejoramiento de la competitividad del sector astillero colombiano a través del desarrollo de capacidades logísticas integradas

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Abstract

The Colombian shipyard sector is characterized by peculiarities that make it differ from other sectors that define its framework of operation, such as technical, technological, economic and institutional aspects and the dynamics of the shipyard market: a global competitive market; few local actors; difficulties to compete at the international level; financial, economic, technological and information asymmetries through its supply chain. Through the development of integrated logistic capacities, as a mechanism for the articulation and promotion of regional clusters, it is possible to improve the competitiveness of the shipyard sector, from the articulation of logistic operations, to achieve competitive advantages that are sustainable over time and leverage the articulation potential of the public, private and academic actors that make up and participate in the sector. Integrated logistics capabilities represent how organizations can leverage their resources in conjunction with other members of their supply chain and the industry in general, to deploy organizational strategies and achieve joint benefits for members. In this research, a prospective and strategic platform is presented to promote the creation of the Colombian shipyard cluster through the development of integrated logistic capacities, based on the utilization of the strategic resources of the sector's stakeholders and the analysis of the potentialities for their integration and development from the perspective of the theory of organizational resources in the context of supply chain management.

Key words: Logistical capacities, competitiveness, cluster.

Resumen

El sector astillero colombiano se caracteriza por particularidades que lo diferencian de otros sectores y que enmarcan su operación, como aspectos técnicos, tecnológicos, económicos e institucionales y las dinámicas propias del mercado astillero: un mercado de competencia global, bajo número de actores locales, dificultades para competir a nivel internacional, asimetrías financieras, económicas, tecnológicas y de información a través de los eslabones de su cadena de suministro. A través del desarrollo de capacidades logísticas integradas, como mecanismo para la articulación y promoción de clústeres regionales, es posible mejorar la competitividad del sector astillero, proponiendo desde la articulación de las operaciones logísticas, el alcanzar ventajas competitivas que sean sostenibles en el tiempo y exploten el potencial de articulación de los actores públicos, privados y académicos que conforman y participan en el sector. Las capacidades logísticas integradas representan la manera en que las organizaciones aprovechan sus recursos conjuntamente con otros miembros de su cadena de suministro y del sector, en pro de desplegar las estrategias organizacionales y conseguir beneficios conjuntos para sus miembros. En esta investigación, se presenta una plataforma prospectiva y estratégica para promover la puesta en marcha del clúster astillero colombiano a través del desarrollo de capacidades logísticas integradas, con base en el aprovechamiento de los recursos estratégicos de los actores del sector y el análisis de las potencialidades para su integración y desarrollo desde la perspectiva de la teoría de los recursos organizacionales en el contexto de la gestión de cadenas de suministro.

Palabras claves: Capacidades logísticas, competitividad, clúster.

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Introduction

The maritime sector is composed in large part by the transport of goods, the shipbuilding industry and the services associated with these activities, represents the engine of the economy of many developed countries and an opportunity for the emerging economies with the geographical conditions and infrastructure necessary for its development.

Maritime trade has increased its share of global cargo transport in recent years, marking a historic record by passing 10 billion tons in 2015, although it reported a slowdown in growth of (2.1%) compared to previous years as a result of the decline in exports and imports, mainly in developed countries *(UNCTAD, 2016)*. With the growth of the maritime industry, the global delivery of offshore vessels tripled between 2004 and 2009 driven by the rise in oil prices and the renewal of the fleets, however in 2015 it slowed down and is expected to decline over the coming years *(OECD, 2015)*.

The sector is currently experiencing a deceleration as a result of the fall in oil prices and trade associated with developed countries, which slowed the ship and naval artifacts building industry. Countries with the greatest participation in shipbuilding are China, the Republic of Korea and Japan, with 91.4% of the global production, in gross tonnage, while Bangladesh, India, Pakistan and China represents 95% of the market of naval artefacts in 2015 *(UNCTAD, 2016, p. 29)*. In the case of Latin America, Brazil and Chile are the largest participants in the sector.

The Maritime Sector faces challenges from technological advances, the data revolution, the growth of e-commerce and the deployment of the fourth industrial revolution. These changes create risks and opportunities that require the development of new business models, to improve logistical performance and develop capacities that allow access to new business opportunities *(UNCTAD, 2016, p. 25)*. Within the maritime sector, the construction of offshore ships implies a high level of flexibility in production processes, high level of coordination, continuous processes of innovation and development, and the strict compliance with norms, regulations and International standards *(OECD, 2015)*.

To improve the competitiveness of the sector, it is necessary to develop new ways of interpreting its characteristics and the economic situation that surrounds it, taking advantage of the current strengths and proposing long and medium-term actions that allow its development, leveraged in research components, knowledge and logistical capacities. This article analyzes the particularities of the Colombian shipyard sector from the perspective of logistical capacities integrated as a mechanism to improve the competitiveness of the sector through collaborative work schemes that integrate the actors of the local and regional supply chain of the shipyard sector. Below the context is presented for logistics in the sector, the potential of integrated logistical capacities and the guidelines to improve its competitiveness.

Logistics and the competitiveness of the sector

Due to the complexity of the naval artifacts a wide variety of materials are needed from different suppliers, both national and international, increasing the complexity of supply management by requiring delivery time limits for assorted materials that conform to the schedules of the projects in progress, so as not to generate downtime or cost overruns as a result of changes in exchange rates, in addition to other aspects. Product development in the ship building industry is characterized by complex processes that involves high volumes of information between multiple tasks, teams and suppliers that converge and act interdependently *(Gronau & Kern, 2004)*.

Analyzing the competitiveness of the Norwegian maritime cluster, under the survey based study of Porter, Benito, Berger, De La Forest, & Shum (2003) it is found that the competitive environment of the sector is widely influenced by the demand conditions which pressures the industry towards continuous improvement, innovation and meeting the customer needs, promoting rivalry among the sector's stakeholders.

This is also the case in Colombia as customers in the sector recognize the degree of personalization of the products and the technological capabilities of the large shipyards to access to their services, motivating the development of capacities and the increase of the efficiency of the market players. In the wake of the competitive landscape, the actors have specialized their services and have focused on the market segments where they have competitive and comparative advantages over the other actors, such as institutional markets, repair services, design, construction, remodeling and painting among others.

This specialization in market segments gives rise to the creation of new joint business strategies that allow other segments to be serviced that each actor has left behind individually, but what could be addressed by connecting several actors in the supply chain, and even generating new businesses or integrating processes vertically or horizontally. In the country, the ship building industry is largely made up of small dedicated workshops dedicated mainly to the repair and construction of small boats and larger size shipyards dedicated to the design, construction and repair of ships, vessels and naval artifacts. The sector has its own dynamics for each type of business according to its size and availability of their own resources and the region where they are, such as human talent, physical and telecommunications infrastructure, support and surveillance of the regional agencies and territorial promotion and control.

The Colombian shipyard sector is characterized by productive configurations according to each project and requires raw materials from national and international suppliers, in a supply chain where each actor makes decisions of provisioning and management of inventories in an autonomous manner and with little information *(Adarme Jaimes, Arango Serna, & Balcázar, 2011)*, which is reflected in the absence of policies for the supply and control of inventories generating high supply costs, delays in the execution of projects and decreased service levels *(Otero, 2012)*.

Therefore there is great potential for the reduction of the costs of the shipyard sector stakeholders by performing the joint planning of their supply chain, sharing information, generating strategies to share benefits through alliances and contracts *(To be with Jaimes, Arango Serna, & Balcázar, 2011)* and to use an intermediate link in the chain to centralize the supply needs and generate the purchasing plans jointly *(To be with Jaimes, Arango Serna, & Balcazar Camacho, 2011)*.

It is necessary to confront the current challenges of the sector, the Productive Transformation Plan *(PTP, 2013)* identifies the low capacity of the Colombian shipyards along with the low productivity of the workforce and the high costs of raw materials, as a result of the lack of integration and the failure to access economies of scale, such as the main causes that affect the performance of the sector.

For which, the prospective focus based on integrated logistic capacities, could help identify the strategic skills of each organization and the possibilities for their integration through the conformation of collaborative structures, such as a regional cluster for the sector, that facilitates the articulation of the actors by overlapping the asymmetries of information and capacities of each organization.

Integration of the logistic capacities in the shipyard sector

The resource-based vision (RBV) emphasizes the organizational strategy linked to organizational capacities as a more stable basis for the formulation of the business strategy that the perspective based on the demand or the external customer (*Grant, 1996)* presenting an alternative approach to the mainstream of conventional competitiveness based primarily on external forces and competitive context.

Organizational capacities are routines or mechanisms that allows the Organizations to Acquire and deploy resources to facilitate the production and delivery of goods and services (Rungtusanatham, Salvador, Forza, & Choi, 2003). The term "capabilities" reflects the role of strategic management in adapting, integrating, and reconfiguring organizational resources, competencies, and skills to respond to changes in the environment *(Gligor & Holcomb, 2012)*.

The logistic capacities are unique skills that are learned, maintained and improved in terms of time and quality to compete, being able to become key competencies of the companies *(Mentzer, Min, & Bobbitt, 2004)*.

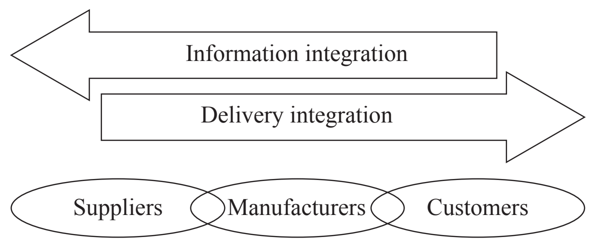
Logistical capacities help companies to collaborate with their supply chain partners in the coordination of supply and demand to generate added value to customers (Mentzer et al., 2004). Logistical capacities are relational and related to the logistic network and arise as a product of inter-organizational learning processes *(Pfohl & Buse, 2000)*.

In the supply chain of the shipyard sector, the resources, capacities and knowledge of multiple organizations converge to achieve the development of a project, so that the chain can be seen as a dynamic network of capacities that must be integrated to meet the project objectives, with it being necessary to research the mechanisms of integration of these capacities *(Ruuska, Ahola, Martinsuo, & Westerholm, 2013)*. It is important to study that processes or capacities allow companies to leverage joint knowledge and complementary resources outside of long-term strategic relationships *(Zacharia, Nix, & Lusch, 2011)*.

The current competitive scope has shifted from the level of individual organizations to supply chains, so organizations must integrate their logistical capabilities with those of their supply chain members *(Gligor & Holcomb, 2014)* therefore the development of process integration capabilities in supply chains, makes it easier for the company to make improvements in its performance, specifically in operational excellence and increased revenue *(Rai, Patnayakuni, & Seth, 2006)*.

In the study of Frohlich & Westbrook (2001), through the International Manufacturing Strategy Survey of 1998, identified that the most successful manufacturers seem to be the ones who have carefully linked their internal processes with their External vendors and customers in unique supply chains (Fig. 1). In order for this integration to be successful it is necessary to identify the concordant and redundant processes throughout the supply chain and to determine at which point the highest value is added in the chain *(Balcazar, 2014)*.

Fig. 1. Supply Chain Integration



Source: Adapted from (Frohlich & Westbrook, 2001, p. 186).

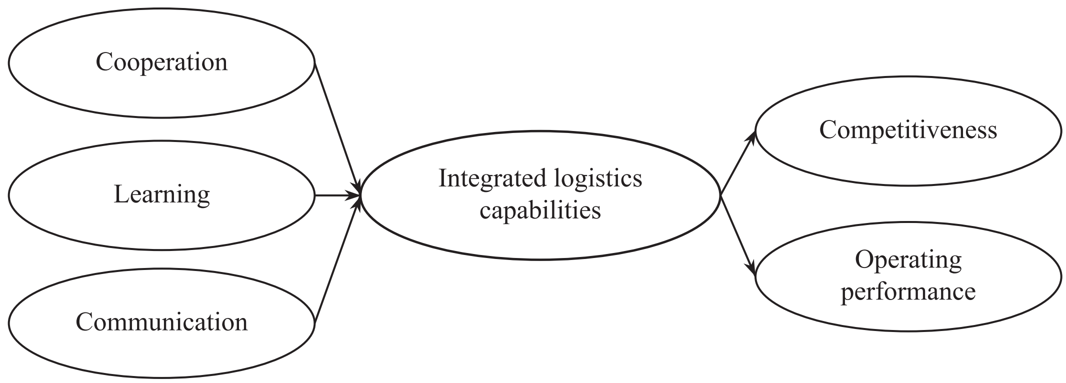
In the context of organizational capacities, the integrated logistic capabilities represent the ability of a local company to have the skills of the organizations that make up its supply chain, so that it can positively affect their performance and that of the organizations that make up their network.

In order for capacity integration to take place, it is first necessary to identify the distinctive logistic capacities of each organization that forms the network and supply chain, and then establish collaborative, integration and coordination mechanisms that can configure forms of joints action and allow organizations to positively affect their competitiveness and performance.

Fig. 2 presents a construct of how integrated logistic capacities can be achieved through the capacities of learning, cooperation and communication *(Esper, Fugate, & Davis-Sramek, 2007; Morash, Dröge, & Vickery, 1996)*. It also shows how the integrated logistic capabilities can influence operational performance and competitiveness *(Lynch, Keller, & Ozment, 2000; Shang & Marlow, 2005)*.

A mechanism to facilitate the integration of logistic capabilities, is the conformation of logistical communities or regional clusters. Through a shipyard cluster it is possible to achieve advantages for the sector and the region. The experiences of other countries show the importance of this

Fig. 2. Construct of logistic capacities and competitiveness



Source: Adapted from (Gligor & Holcomb, 2014, p. 220)

type of integration strategy by facilitating the communication of the members of the cluster with other sectors *(Benito et al., 2003)* and its potential to initiate collaborative engineering processes *(Gronau & Kern, 2004)*.

Through a shipyard cluster it is possible to mitigate the negative effects on the overall performance of the supply chain, caused by the asymmetries of the sector and its supply chain. By acting as a central node in the sector, to channel, align and promote the standardization of information flows, action mechanics and good practices in the sector, the cluster figure facilitates the communication and information flows between stakeholders in the sector and the collective construction of strategic positions.

Prospective platform to improve the competitiveness of the sector

The ship building industry has been developed as a knowledge-intensive industry with high contributions from the service sectors, so the prospective technology can be used to analyze possible scenarios and define sectoral priorities by contemplating the perspectives of industry and supply chain experts to identify problems and propose solutions that respond to the challenges of the sector *(Vishnevskiy, Karasev, Meissner, Razheva, & Klubova, 2015)*.

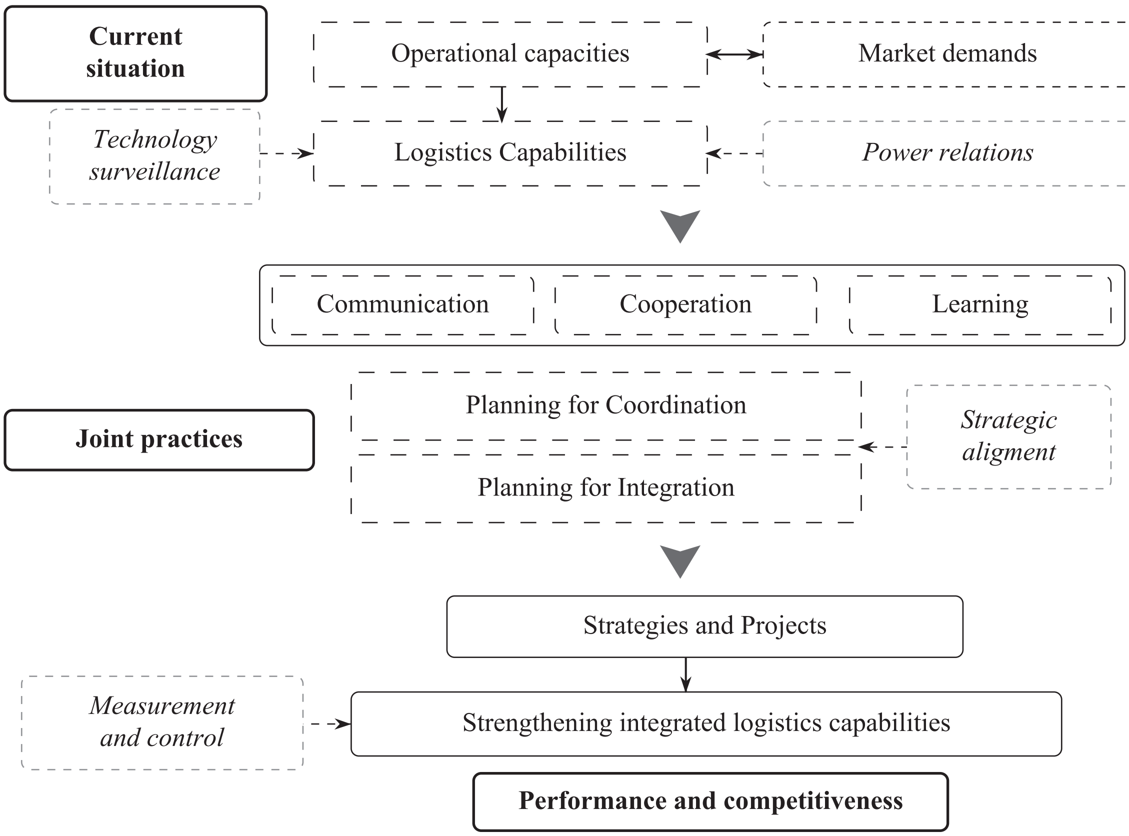
For the construction of a prospective platform focused on competitiveness, it is possible to appropriate elements of the technological vigilance. From the methodologies for the formulation of technological strategies reviewed by Castellanos, Ramírez, Fúquene, Quintero, & Fonseca (2013) common phases are identified that can be applied to the construction of the prospective platform of the shipyard sector: 1) Evaluation of the current situation, 2) Evaluation of capacities, 3) Project identification, 4) Definition of the strategy and 5) Implementation and control. Phases that can be aligned by the construct of integrated logistic capabilities presented in Fig. 3.

Assessment of the current situation

In the first phase of the prospective platform to improve the competitiveness of the shipyard sector, the characteristics of the supply chain of the shipyard sector are identified, together with the different companies that constitute it and their degree of specialization, as well as the roles they play within the chain. At this stage, public, private, educational and institutional actors are identified that directly influence, through their actions, or indirectly through the establishment of limiting conditions or that encourage and promote the activities of the sector.

After the recognition of the actors, it is necessary to determine the strategic relationships between the companies of the shipbuilding cluster in terms of Interaction with other actors in the supply chain and the degree of influence of the actors within the sector and the local economy. The main

Fig. 3. Prospective platform of the Colombian shipyard sector



Source: The authors based on Balcazar (2014, p. 24) and Balcázar Camacho, López Bello, and Jaimes (2016)

actors should be identified, as well as the possible strategies for their integration and support of the cluster's plans, such as the strategic providers of services, information, knowledge, training, inputs, raw materials and technologies, as well as local and regional institutional actors.

Including elements of the Porter diamond, the phase of the current situation also includes the identification of the external elements of the sector as well as the requirements of the international market and the current panorama of the competitors of the region, their services, capacities and added values that generate competitive advantages in the market.

Using techniques of collective knowledge construction, through prospective processes with industry experts, from different perspectives: academic, business and institutional, it is possible to evaluate these elements and identify common points and interests as well as the concerns of stakeholders and other elements that will guide the identification of project opportunities.

Capacity assessment

Starting from the identification of the local resources, geographical, economic, and social conditions and internal and global demand, the resources in conjunction with the cluster organizations can be aligned to provide competitive advantages in the face of the market needs. To this end, the resources must be hard to imitate, valuable and rare *(Barney, 1991)*. These resources can be articulated through the deployment of integrated logistic capabilities.

Capabilities include the identification and recognition of tangible and intangible resources that can be used to generate them, such as the routines, strategic values, operations policies, shared practices, among others. In order to measure these capacities it is necessary to develop measuring scales that allow the degree of group and individual advancement of the organizations to be evidenced with regard to the capacities.

The resources of cluster organizations can be directed towards building Integrated Logistics capacities that impact logistical performance *(Ralston, Grawe, & Daugherty, 2013)* and the overall performance of the sector's supply chains. For example, the articulation of business information systems and the application of information and telecommunications technologies enables the development of information-based logistical capabilities that directly influence the logistical performance of the supply chain *(Zhao, Dell, & Stench, 2001)*.

The logistical capacities can be classified in: demand-oriented, such as customer service, time and capacity of response to the market; oriented to supply or operational such as the availability of products and the total cost of distribution (*Morash et al., 1996)* and learning-oriented *(Esper et al., 2007)*, such as routines, knowledge and shared assumptions.

By identifying these capacities and their degree of individual development by the members of the cluster, it is also possible, with the interdisciplinary and inter-company participation of experts, to propose mechanisms and strategies for their development and integration.

Project identification

The potential of the shipyard sector and its supply network to take advantage of market opportunities and develop new services and solutions, based on the generation of joint action strategies, can be contemplated from several capacities: Communication, Cooperation, Coordination and Integration. For the deployment and implementation of joint projects, the shaping of an organizational scheme, such as a cluster, can facilitate the design and adoption of mechanisms that facilitate the communication, cooperation, coordination and integration, by defining predetermined procedures, rules, and agreements that serve as the basis for and establish the minimum requirements for each type of action between cluster members and the supply chain.

The collaboration schemes in the shipyard sector are not new strategies, when the market requires large projects, the organizations go to other specialized firms to collaborate on specific aspects of the projects, without these being considered as direct competitors. These trust-based relationships provide high degrees of flexibility and enable organizations to focus on their core competencies *(Lechner & Dowling, 2003)*.

Through mechanisms to improve communication among sector participants, organizations can improve their competitive advantages by investing in research and development or through their inter-organizational linkages, such as alliances and networks that facilitate knowledge flows and collaborative learning processes *(Caiazza, Richardson, & Audretsch, 2015)*.

Project opportunities are not limited only to the use of new market and operational opportunities. The technological appropriation and the adoption of standards within the sector requires first of all the adoption of change management strategies, organizational learning and knowledge management that facilitate the adoption and transfer of technologies, practices and experiences among the members of the sector to boost the growth of the sector (Paine et al., 2013), and projects for the internal strengthening of industry organizations can also be evidenced. Customised training processes, dissemination of standards, appropriation and technology transfer are identified at this stage.

In terms of information and communications management, the shipyard cluster can facilitate the creation of market networks. Through market networks, focal companies can leverage their relationships to gain more information about market demands and new product requirements, to reach new markets or customers *(Lechner & Dowling, 2003)*.

Defining the Strategy

The definition of the sector's strategy is part of the identification of the goals of the organizations that make up the sector and can become integrated goals of the shipyard cluster. It is necessary to contemplate the objectives that overlap the individual interests and allow global benefits for the supply chains and organizations of the sector to be achieved. The benefits must be deployed throughout the supply chains, through mechanisms such as contracts to share benefits or periodic renegotiations that improve the initial offers in accordance with the benefits derived from the deployment of communication, cooperation, coordination and integration mechanisms.

For the coordination and integration of capacities of the shipyard sector based on logistical operations, it is possible to use strategies to share information about the supply and the requirements of materials and means of transport and production, among others. By identifying coincidences in the projections of purchases, and/or use of means and procurement of services, it is possible to develop integrated planning strategies, or at least those coordinated from operations focused on the not generating interferences and non-overutilization of resources in the region, as a result of the convergence of major projects. These phenomena can induce periods of shortages of qualified human talent, inputs or logistic services of supply, transport and storage, among others, and even provoke artificial spikes in prices as a consequence of the momentary scarcity or lack of availability, which negatively affects the sector.

The strategic alignment of the cluster must overlap the power relationships identified in the supply chains of the sector and determine stratified strategies that can be adopted to fit the capacities of each one of the actors of the chain as they are developed.

Cluster strategies should promote the development of integrated logistics capabilities based on identified resources.

Implementation and control

After identifying project opportunities through activities of communication, cooperation, coordination and integration, and to define the minimum standards and mechanisms for their implementation in specific projects, it is also necessary to develop mechanisms for monitoring and controlling the strategy of the cluster and the achievement of the objectives of the sector when faced with changes in the market and the socioeconomic conditions of the region.

The central objective of the control of the deployment of the strategies and joint plans of the cluster is the improvement of the processes through the supply networks of the actors of the sector. It is necessary to develop a better understanding of how performance measures contribute to or limit the use of existing capacities or the identification of new strategic skills *(Grafton, Lillis, & Widener, 2010)*. By focusing on one indicator or another, it is necessary to monitor efficiency and resource utilization relationships in the processes rather than gross or aggregate results that simply focus on volumes, such as: Sales, revenue, profitability, indicators that show individual results, beyond the joint goals of the sector.

A shipyard sector performance management system should not only allow performance measurement, but also the policies, emotions, behaviors *(Gunasekaran & Kobu, 2007)* and joint actions of the members of the supply chain. The performance measures should not be limited to categories such as quality, time, flexibility and costs, but be inclusive, universal, measurable and consistent with the goals of the organizations and the supply chain of the actors in the sector *(Beamon, 1999)*.

The development of a control and monitoring system for the prospective platform of the Colombian shipyard sector should consider the differences between the organizations that make it up and the use of measures that drive the improvement of processes, the adoption of good practices, the implementation of collaborative activities and the degree of use of joint resources for adding value among stakeholders in the sector.

Discussion

The Colombian shipyard sector presents great opportunities to increase its participation in economic development and that of the regions, with it being necessary to promote integration and joint action strategies that allow advantage to be taken of new business opportunities and joint research processes, obtain access economies of scale, development and transference. To do so the development of associative structures such as a regional cluster would facilitate the implementation of collaborative engineering communities for the design, construction, repair and development of services related to the main processes of the shipyard sector, promoting the creation of new businesses and the application of new technologies. To facilitate the implementation of these strategies, the study and development of integrated logistic capacities in the context of a prospective agenda for the sector, can contribute to the joint improvement of productivity and competitiveness of the sector and facilitate its interaction with the institutions and the education sector through training, strengthening, research and transfer processes according to the consolidated needs of stakeholders in the sector.

It is necessary to study the way in which the current logistic capacities of the members of the shipyard sector are configured, identifying the concordances and dissonances, as well as their potential to be integrated. It is possible to propose mechanisms for the gradual integration of logistical capacities by initiating the least specialized ones until fundamental and distinctive capacities are obtained. Project support processes such as the management of purchasing, acquisition of services and training processes, development, research and transference, show great potential for its integration within the sector.

International studies show that the shipyard sector faces great challenges involving the adoption of new technologies and improving operations in accordance with the ever-increasing demands of the market and standards. Addressing these challenges individually can lead Colombian shipyards to incur large costs and high levels of risk to stay competitive in the international market. A consolidated shipyard cluster projects the joint action of the sector and dynamizes the improvement of its operations and interactions with other sectors. It could help address these challenges and gain access to new business opportunities, economies of scale, technological advances, and market and other information, increasing the competitiveness of the sector and achieving joint benefits for its members. Identifying and quantifying organizational and inter-organizational resources that can lead to the development of logistical capacities is a work that requires customised research processes and the development of constructs that support their measurement. It is necessary to look for alternatives that promote the development of these research processes, linking the educational sector and the government agencies promoting science, technology, development and innovation for the construction of specific agendas in the shipyard sector.

In future jobs it is necessary to find ways to operationalize and verify the construct of integrated logistic capabilities in the shipyard sector (Figure 1.) and mechanisms for its measurement and control from the proposed prospective platform. Integrated logistical capacities in the context of joint action and collaboration strategies as a regional cluster, can facilitate the development of collaborative engineering communities that are linked to the research processes of higher education institutions in articulation with the strategies of regional strengthening of the public institutions. It is necessary to propose research that studies the design of mechanisms to facilitate and promote these types of public-private partnership structures in supply chains with a large number of actors, high levels of uncertainty and asymmetries of information and resources, such as those of the shipyard sector.

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Equivalent SPS Compact Double Hull (CDH) Bottom Structure Grounding of Inland Waterway Barges

Encalle de Estructura Inferior de Casco Doble Compacto (CDC) Equivalente SPS en Barcazas de Navegación Interior

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Abstract

MARPOL regulations stipulate that all single hull oil carrying barges must be made of double skin construction or modified by an alternate construction provided that the construction ensures at least the same level of protection against oil pollution. It is be demonstrated that the proposed alternative method of design, made with a SPS Compact Double Hull (CDH) applied to the bottom hull, does not rupture under the prescribed grounding event (no rupture, no oil outflow, no oil pollution).

A sophisticated finite element model was developed to simulate the grounding event for a single hull barge. Based on the experience gained from this simulation, a comparative grounding simulation study was conducted where a specified embedded object causes rupture of the outer and inner hull for double hull construction (a non-zero probability of oil outflow and pollution) and no rupture of the SPS CDH which demonstrates superior performance.

Key words: Equivalent or superior performance, impact resistant hull structure, robust bow construction, Sandwich Plate System (SPS), Compact Double Hull (CDH).

Resumen

Las regulaciones de MARPOL estipulan que las barcazas de casco sencillo deben ser hechas a partir de una construcción doble casco o modificadas por un método alternativo que asegure al menos el mismo nivel de protección contra los derrames de petróleo. Se ha demostrado que el método de diseño alternativo propuesto, hecho con un doble casco compacto (CDH) de SPS (Sandwich Plate System) aplicado en el fondo de la embarcación no sufre ruptura sobre eventos encalle (no hay ruptura, no hay flujo de petróleo, no hay contaminación por petróleo). Un modelo de elementos finitos sofisticado fue desarrollado para simular un evento donde una barcaza de casco sencillo encalla. Basada en la experiencia obtenida de esta simulación, un estudio de simulación comparativo fue desarrollado donde un objeto embebido causa la ruptura de la parte exterior e interior de un casco con construcción de doble casco (una probabilidad distinta a cero de flujo de combustible y contaminación) y la no ruptura del doble casco compacto con SPS mostrando un mejor desempeño.

Palabras claves: Rendimiento equivalente o superior, estructura de casco resistente a impactos, construcción de arco robusta, sistema de placa sándwich (SPS), doble casco compacto (CDH).

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Introduction

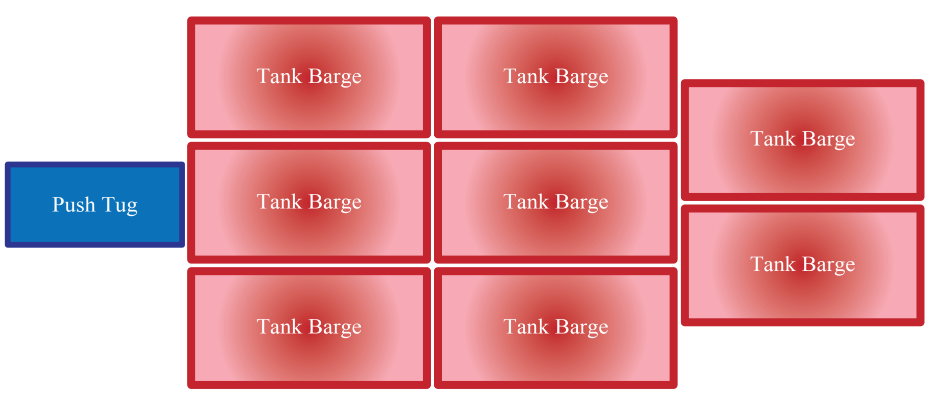
The ABS Rules for Building and Classing Steel Vessels for Service on Rivers & Intracoastal Waterways[1] (ABS, 2016) stipulate a double hull dimension of 610 mm (2 ft) for protection against oil pollution in the event of a collision or grounding event and a minimum clearance of 460 mm (18 in.) for passage between framing throughout the double sides and double bottom. These requirements are specified by the Code of Federal Regulations (CFR), Title 33, Chapter I, Subchapter O, Part 157 Subpart B, Section 157.10d(d). The structure that satisfies the current regulations is a double hull barge with double sided and double bottom construction designed in accordance with Resolution MEPC.110 (49) "Revised Interim Guidelines for the Approval of Alternative Methods of Design and Construction of Oil Tankers under Regulation 13F(5) of Annex I of MARPOL 73/78"[4] (International Maritime Organization, 2003). The double hull barge construction inherently has oil outflow characteristics for a certain grounding event that are in accordance with MEPC.110 (49)[4].

MARPOL regulations[3] (International Maritime Organization, 1973) stipulate that all single hull oil carrying barges must be made of double skin construction or modified by an alternate construction provided that the construction ensures at least the same level of protection against oil pollution. It can be demonstrated by calculation, using appropriate calculating procedures, that the proposed alternative method of design, made with a SPS Compact Double Hull (CDH) applied to the bottom hull does not rupture under the prescribed grounding event ***(no rupture, no oil outflow, no oil pollution)***.

The barge convoy used for this study typically operates in a variety of different configurations, where one such configuration is illustrated in Fig. 1 consisting of 8 barges and a push tug with a total mass of 10,514 tonnes and a maximum velocity of 16 km/hr (4.44 m/s). The kinetic energy is equal to 104 MJ. For navigational channels that are dredged regularly, the conditions of the river bed (soil type and maximum rock size) are well known. It is assumed that the river bed is mostly sand with some small areas of rocks with a maximum diameter of 100 mm which are washed downstream.

A grounding simulation for a single hull barge structure was initially undertaken to demonstrate that the modeling assumptions are appropriate and that the simulation is a reasonable representation of the actual conditions. Based on the results from this simulation, a comparative grounding simulation study for the double hull construction and SPS CDH construction was completed[2] (Intelligent Engineering, 2016). The performance evaluation of the two barge conversion options including an introduction of the two structural configurations, design criteria, details of the finite element model and interpretation of the simulation results are presented.

Fig. 1. Barge Convoy



Rationale to Satisfy Regulations

Part 3, Chapter 2, Section 1, Clause 5.5 of the ABS Rules for Building and Classing Steel Vessels for Service on Rivers & Intracoastal Waterways[1] stipulates a double hull dimension of 610 mm for protection against oil pollution in the event of a collision or grounding event. This rule is dictated by the requirement to provide access to complete welding operations during the construction of the double bottom. The structure that satisfies the current regulations is a double hull barge with double sided and double bottom construction designed in accordance with Resolution MEPC.110 (49)[4]. The double hull barge construction inherently has oil outflow characteristics for a certain grounding event that are in accordance with MEPC.110 (49)[4].

Resolution MEPC.110 (49)[4] employs a probabilistic methodology to determine the pollution prevention index to evaluate equivalency of a design concept to a double-hull design and recognizes that oil outflow will occur with some probability. It can be demonstrated by calculation, using appropriate calculating procedures, that the proposed alternative method of design, made with a SPS CDH applied to the bottom hull, does not rupture under the prescribed grounding event (no rupture, no oil outflow, no oil pollution). The alternative would then be equivalent or better than the double-hull design which ruptures for the same grounding event (a on-zero probability of oil outflow and pollution). ABAQUS 2016 *(Simulia, 2016)*[6] will be used to conduct the grounding event simulation calculations in accordance with Clause 6.2.1 of Resolution MEPC.110 (49)[4].

Double Hull Construction

The double hull construction is typically applied along the cargo tank region and tapered over a small localized area of the bow region. Fig. 2 illustrates a typical mid-ship section of a conventional double hull design. A typical method for the conversion of a single hull construction to double hull construction involves welding the outer hull and additional internal structure to the existing inner hull. The space between the inner and outer hull is 610 mm making it problematic to complete weld operations and conduct inspections. Furthermore, conversion using the aforementioned method has the following disadvantages: additional complex structure with new confined spaces; increased material and labour costs associated with processes such as surface preparation, shop priming and coating; increase in construction schedule, reduction in cargo capacity and; increased inspection and maintenance requirements.

The ABS Rules which stipulate that single hull barges are to be converted to double hull construction only apply to the cargo tank region. The transition section for the double bottom construction which occurs from the cargo tank region into the bow section, as illustrated in Fig. 3, are not given any special consideration within the

Fig. 2. Barge Convoy

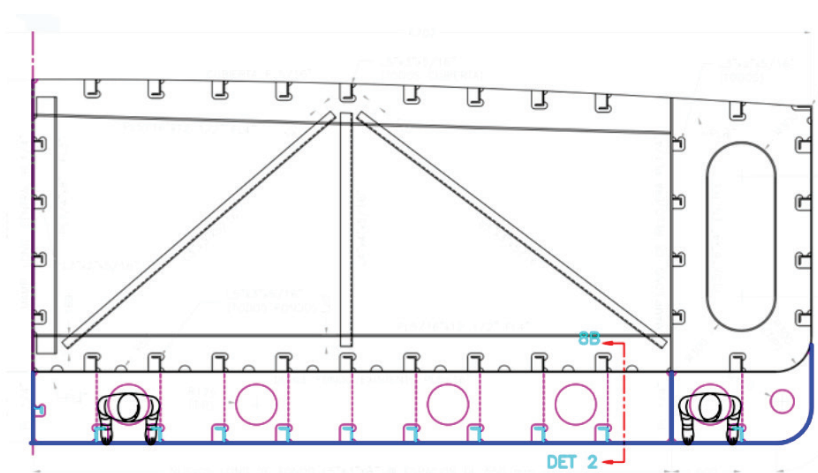
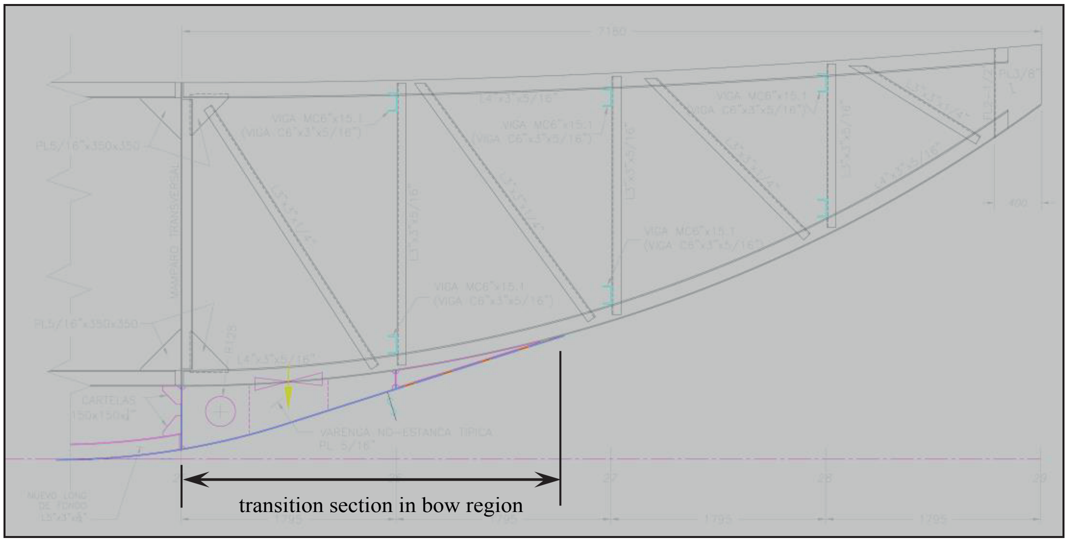


Fig. 3. Transition of Double Bottom Structure at Bow Region



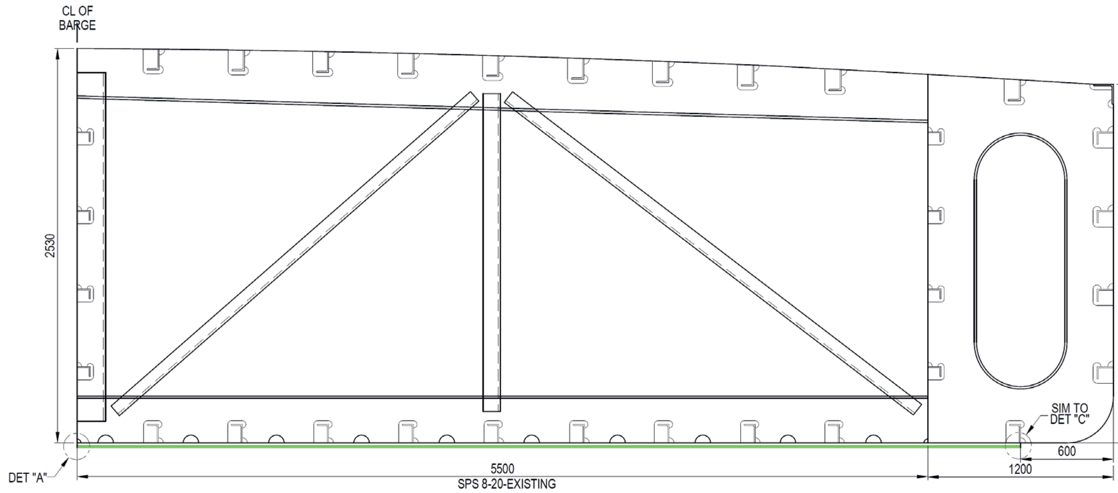
rules. The nature of the grounding event is such that initial impact occurs at the bow and causes damage along the length of barge continuing through to the first transverse bulkhead where rupture may occur in the outer hull or both the outer and inner hull. This type of event is not a collision event as the barge should ride over top of the embedded objects. The most important section of the vessel with respect to grounding events is the bow region which for conventional double hull conversions can only be made solid from the outside and are welded to the framing structure on the inside as accessibility is difficult which can result in poor workmanship, poor welding quality and lead to corrosion issues. The numerous intersecting steel pieces make it more prone to crack propagation, fracture and rupture at locations of stress concentrations. These issues and concerns associated with double hull construction are addressed with the proposed SPS CDH design which is described in the following section.

SPS CDH Construction

SPS CDH construction provides risk reduction benefits over that of double hull construction including: a significant increase in impact resistance, a strengthened bottom structure that reduces critical stresses, schedule reduction for fabrication and installation, reduced risks during fabrication, less maintenance, and elimination of risks and costs for through life void space inspections.

For the SPS CDH construction, as illustrated in Figure 4, the issues described in the previous section for the double hull construction are advantageously eliminated and/or addressed. The SPS CDH design eliminates problems associated with welding and accessibility as all construction is from the outside. The bow section, cargo tank regions and areas beyond the cargo tanks on the aft end are armoured with a SPS Overlay across the full width from halfway within the double sides (as illustrated in Fig. 4 and drawings in Appendix A) which offers greater impact resistance for a specified grounding event. The armoured bow section, which consists of a thicker SPS Overlay (12 mm thick faceplate and 20 mm thick polyurethane core), properly recognizes the type of event as the greatest protection is placed where the initial impact is anticipated. By increasing the amount of steel area associated with plastic deformation for areas beyond the first transverse bulkhead, rupture is prevented where the energy from the initial hit is absorbed. Full length protection is required as the barge convoy has sufficient mass, velocity and kinetic energy (104 MJ) that it will run completely over top of the embedded object without stopping.

Fig. 4. Structural Arrangement for SPS CDH



SPS CDH construction will provide the required protection where rupture is prevented for a specified grounding event. No rupture, no oil outflow, no oil pollution. If the outer hull of the comparative double hull bottom structure ruptures for the same grounding event, then there is a non-zero probability that cracks about the rupture for this high energy event will propagate through the webs of interconnecting steel into the inner hull leading to oil outflow. The rupture of both the outer hull and inner hull would directly lead to oil outflow. The SPS CDH construction must then be considered to be equivalent to or better than a double bottom hull for protection against oil outflow and oil pollution.

Grounding Simulation for Single Hull Barge

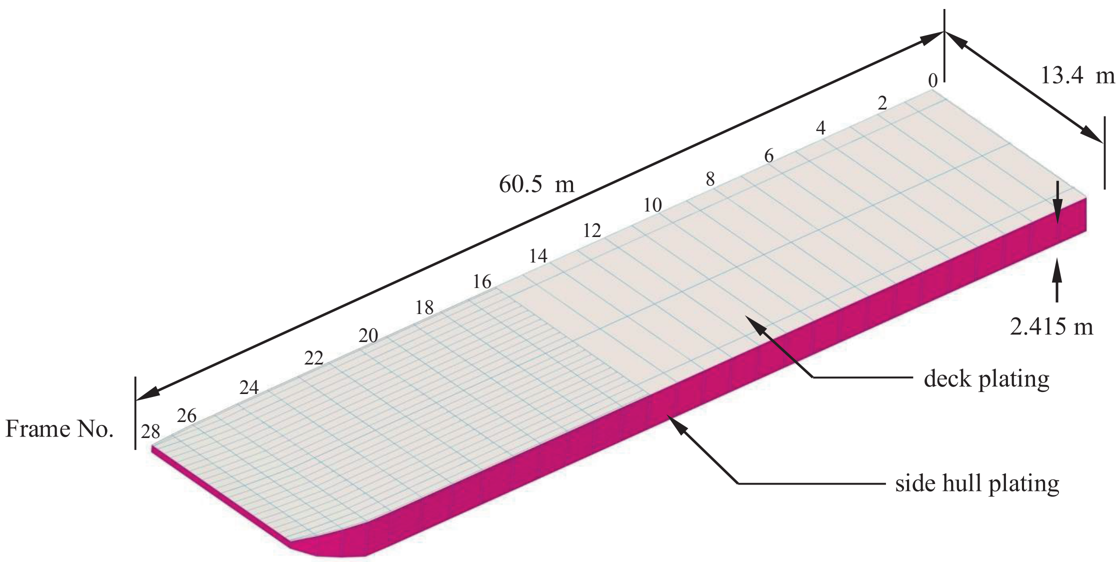
A grounding simulation for a single hull barge structure was conducted using ABAQUS to: ensure the simulation of a grounding event is a reasonable representation of the actual conditions; verify that the soil characteristics and behaviour are accurately modeled and; evaluate the effect of different embedded object shapes.

Geometry and Barge Model Description

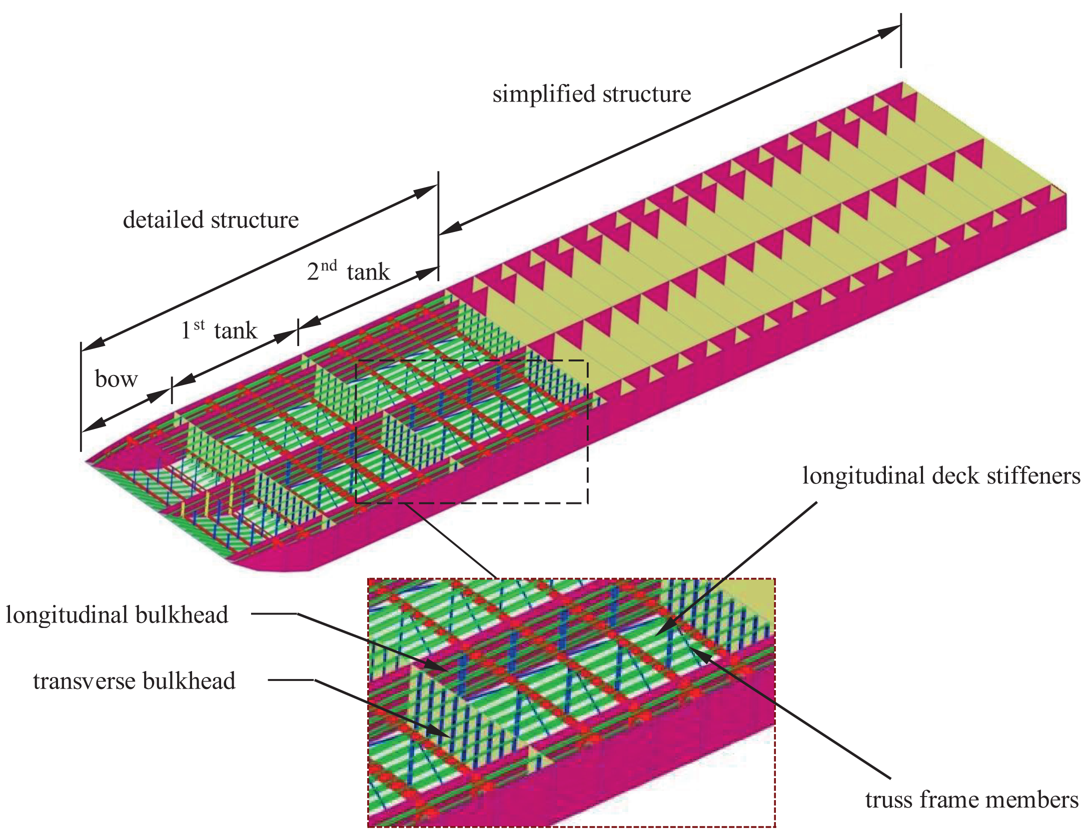
IE has constructed a finite element model representation of the barge convoy using SolidWorks 2016 as illustrated in Fig. 5. The barge convoy consists of 8 barges and a push tug with a total mass of 10,514 tonnes and travels with a maximum velocity of 16 km/hr (4.44 m/s) which gives a kinetic energy equal to 104 MJ. The detailed structure of the model includes the bow, 1st tank and 2nd tank, as illustrated in Fig. 5b, which represents a single barge. The simplified structure of the model represents the remaining parts of the barge convoy (7 adjoining barges and push tug) which are modeled as added mass (including oil in tanks). The simplification of the structure beyond the 2nd tank and the use of shell elements improve the computational efficiency of the analyses. The bottom plating of the single hull construction consists of a single layer of stiffened steel plate schematically illustrated in Fig. 6. An average thickness of 8 mm was used for the bottom plating and was determined from ultrasonic thickness measurements.

A series of full explicit dynamic analyses with appropriate material properties and dynamic parameters have been conducted (SolidWorks geometry model exported into ABAQUS 2016) to investigate the effect of different embedded object size, shape and configurations on the damage caused from a grounding event. The embedded object can either be classified as a rock or a man-made object of an unknown description (ex. spud). The mass of the barge convoy is a million times greater than the mass of a prescribed 100 mm spherical rock which is ~10 kg. The barge

Fig. 5. Barge Geometry and Structure

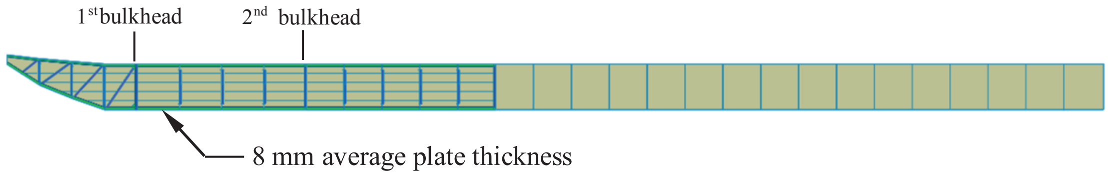


(a) Top Side View



(b) Top Side View with Deck Plating Removed

Fig. 6. Single Hull Barge Model



convoy simply pushes these small rocks into the sandy soil with no damage to the original barge structure. Obviously, the amount of damage will increase with an increase in rock size. The shape of the rock and its orientation with sharp edges could cause local rupture of hull plating. Regardless of the embedded object size, shape or orientation, the kinetic energy is so large that the barge convoy will pass over the object causing damage along the full length of the barge. The magnitude and extent of the damage is directly related to the embedded object geometry, the resistance of the soil provided to the object as it is embedded into the soil mass and to the vertical force exerted on the object as the barge convoy bounces along over top. The vertical force exerted downward (gravity) when the barge is deflected upwards by the embedded objects that it rides over top of is described in more detail in Section 3.3. This will vary depending upon the extent to which the barge convoy is displaced out of the water relative to the draft position. To simplify the analyses this is assumed to be a constant.

Soil Characteristics and Properties

The soil characteristics and properties selected for the grounding simulation was based on a loose sandy layer. The exact material properties for the sand were not available hence the material properties were selected based on two references. The density, modulus of elasticity and Poisson's ratio of the soil were chosen based on Subramanian (2016)[7]. The plasticity material input data, which includes the friction angle, latency angle and cohesion, were selected based on a research paper by Pichler (2012) [5]. Table 1 below gives the material properties and plastic material input data used for modeling the soil for the grounding simulation.

To determine a suitable cohesion value, a model of the embedded object penetrating into the soil was built and a cohesion value was calibrated based on the model. The cohesion value was determined to be 0.05 however ABAQUS automatically adjusts this value to 0.1 which is the minimum cohesion value used for the grounding simulations.

Table 1. Material Properties and Plastic Material Input Data for Soil

Material Properties	Value
Density, kg/m^3	2000[1]
Modulus of Elasticity, MPa	20[1]
Poisson's Ratio	0.2[1]
Plastic Material Input Data	
Friction Angle, degrees	30
Latency Angle, degrees	0
Cohesion, MPa	0.1

[1]Values suggested by Subramanian (2016)[7] are: density (1700-2100 kg/m^3); modulus of elasticity (10-24 MPa); Poisson's Ratio (0.2)

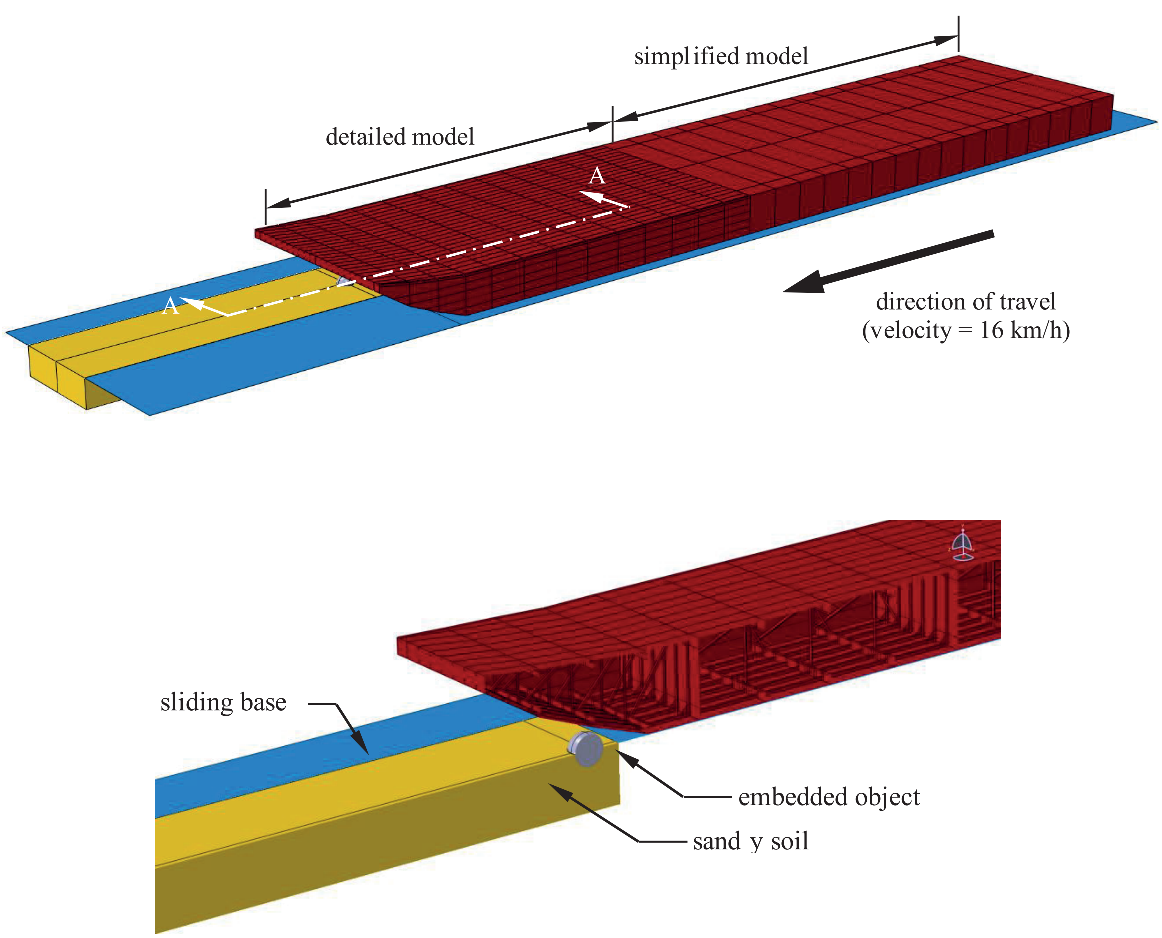
Fig. 7 illustrates the sandy soil and the sliding base on which the barge sits. The sliding base was fully restrained in all degrees of freedom to simulate the buoyant force. The soil beneath the barge was modeled using Coupled Eulerian Lagrange (CEL) elements to avoid excessive distortion. The degree of freedom normal to the surfaces of the ground was restrained to prevent soil outflow. The embedded object was positioned right between two longitudinal stiffeners in front of the barge and half buried in the ground. The contact between the barge and sliding base is frictionless, while the friction coefficient for all the other parts was assumed to be 0.3. The sandy soil measures 4 m in depth and 6 m in width for the single hull barge and SPS CDH models and 9.5 m in width for the double hull barge model. For the double hull model, the soil behaviour (movement) was influenced by the accumulation of soil mass in front of the barge and subsequent lateral displacement of the soil which extended beyond the specified CEL boundary. The width of the CEL boundary was increased for the double hull model to ensure that the soil is capable of displacing laterally without accumulation (build-up) of soil near the longitudinal CEL boundary.

Fig. 8 illustrates the Eulerian and Lagrangian components of the soil base. The actual soil including the embedment depth of the embedded object was created using a Lagrangian mesh. The Eularian mesh was created to specify the boundaries within which the soil can flow. A soil depth of 1.5 m over the sliding base elevation was selected to allow soil flow in the vertical direction.

Buoyancy Uplift Force

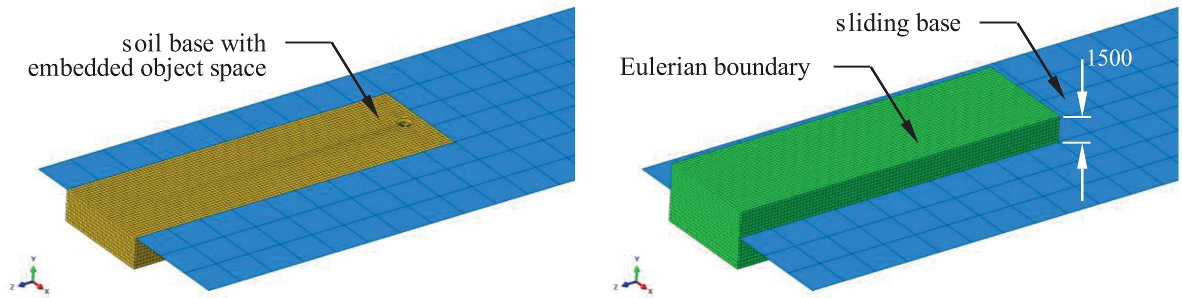
The buoyancy uplift force is equal to the volume of water displaced by the barge, counteracting the weight of the barge plus the vertical load (oil barrels). As the barge hits the embedded object, it is assumed that that the extreme position occurs when the front is lifted 1 m as illustrated in Figure 9b. For a 1 m width of the barge, the change in area of water can be used to estimate the gravity force on the barge after impact. Based on the geometry of the barge as shown in Fig. 9, V1 and V2 are approximately 102 m^3 and 72 m^3 respectively which give a reduction in the buoyancy force of approximately 30%. For this reason, it is assumed that the vertical gravity force acting on the barge is 0.3g during the entire analysis. This may not be the case under real operating conditions because the gravity reaches this magnitude only when the tip is raised 1 m,

Fig. 7. ABAQUS Model Description of Barge on Sliding Base and Sandy Soil



Section A -A

Fig. 8. Lagrangian and Eulerian Elements for the Soil



and will be less than this amount when the barge is fully horizontal. It is conservatively assumed that the gravity force of 0.3g is acting on the barge in the vertical direction during the entire simulation.

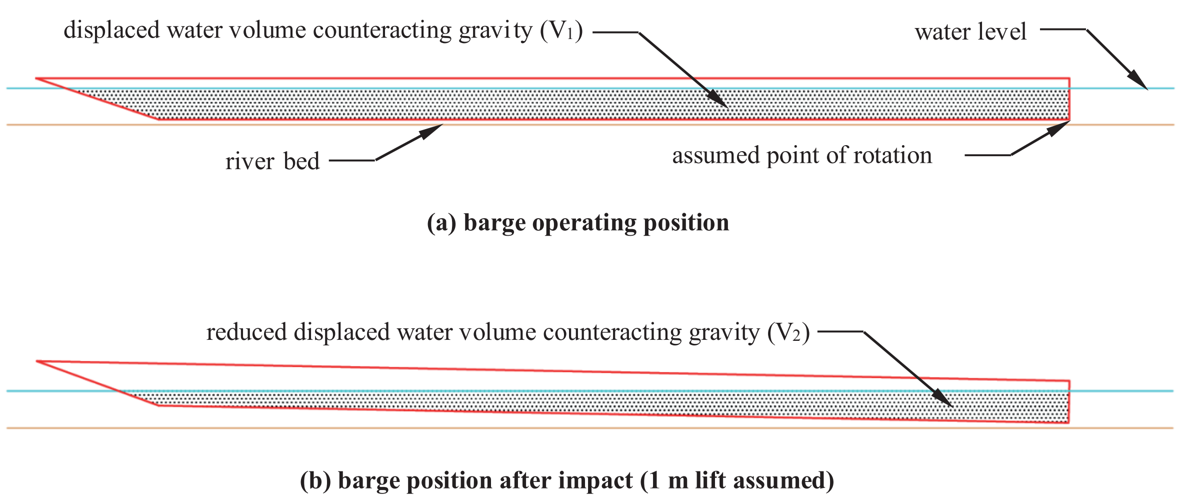
Embedded Grounding Object Configurations

In the analyses, different types of grounding objects with various dimensions and shapes were modeled such as a spherical, rectangular block shape and a prism-block shape object. All objects were partially buried with varying depths and orientations. The effect of the embedded object shape on the damage underneath the barge was unknown, therefore for simplicity a spherical object with a diameter of 100 mm was selected as the first object. The rock was buried 50 mm in the sand. The magnitude of kinetic energy of the barge (104 MJ) caused the rock to be rolled and immediately pushed into the sand. To permit more damage accumulation to the barge, rocks with larger diameters (250 mm, 500 mm, 1000 mm, and 1200 mm) were examined. It was found that larger rocks, typically larger than 500 mm in diameter were capable of substantially damaging the bottom of the barge along the length. Larger spherical objects started to roll with the barge and move along its direction due to contact and friction, especially when the object hit hard spots such as the end of the bow. The object also penetrated in the sand as the barge moved over them, causing yielding underneath the barge and in some cases rupture.

Modeling Assumptions

Considering that the mechanism of grounding events is extremely complex in reality, finite element analysis is not capable of simulating all the aspects of the events. To simplify the problem and simulate the

Fig. 9. Barge Position Before and After Grounding Event



grounding events more efficiently and accurately, a list of assumptions were made and are given below:

- Non-structural mass of 1014 tonnes was added to the bottom plate of the barge from Frame 0 to Frame 23 (frame axis shown in Figure 5) to take into account the weight of oil.
- Extra mass was introduced to the end of barge to consider the influence of the other 7 barges and a push tug.
- Gravity was reduced to 0.3g to account for buoyancy.
- The embedded grounding object was assumed to be highly non-deformable to minimize the effect of object deformations during the grounding event.
- Shell elements were used for the barge, and solid elements for the rocks.
- The maximum mesh size for the detailed and simplified part of the barge was 290 mm and 1200 mm respectively; the maximum mesh size for the locations directly under impact was refined to 100 mm to ensure the extent of plastic deformation is accurately predicted.
- Reduced elements were used for all the elements in the barge except the locations under direct impact.
- Coupled Eulerian-Lagrangian (CEL) solid elements were used to model the soil and avoid excessive distortion in elements.
- The thickness of the plates and members were extracted from details of existing barges.

Material Models

A nonlinear explicit dynamic analysis was performed using non-linear material behaviour

Table 2. Material Properties for the Barge Model

Material	Assignment	Density (kg/m^3)	Elastic Behaviour: Modulus of Elasticity, E (MPa)	Elastic Behaviour: Poisson's Ratio, v	Plastic Behaviour	Damage Criteria
S235 steel (equivalent to ASTM A131 Grade A)	barge[1]	7850	200,000	0.3	nonlinear stress strain curve	Ductile Damage Model: constant fracture strain of 0.18 and strain rate of 0.01; Fracture Energy[3]: 1500 kJ/m^2
sand	ground	2000	20	0.2	Mohr Coulomb Model: friction angle of 30°; dilation angle of 0°; cohesion yield stress of 50 kPa for plastic strain ranging from 0.0 to 0.1	-
artificial material	embedded object[2]	2700	200,000	0.3		-
polyurethane elastomer	elastomer core in SPS	1150	750	0.36		Ductile Damage Model: constant fracture strain of 0.2 and strain rate of 0.01; Fracture Energy[3]: 200 kJ/m^2

[1] Includes hull plates, framing members, stiffeners and steel faceplates in SPS
[2] Referred to as a rock or man-made object
[3] Fracture energy of 1500 kJ/m^2 obtained from steel coupon tests; fracture energy of 200 kJ/m^2 for polyurethane is assumed value

for the model with the exception of the embedded object where a high elastic modulus, equivalent to steel, representing a rigid object was used. The material properties and damage criteria defined for each component of the barge model are summarized in Table 2.

The ductile damage initiation criterion for metals in ABAQUS was used for the fracture simulation. The post-damage behaviour which controls stiffness degradation of the material was included in the simulation by using the damage evolution feature of ABAQUS. As the damage criteria is satisfied, stiffness degradation is applied to the material and the element starts losing its stiffness until a point where the plastic strain in the entire element reaches the specified fracture strain. The element will be removed if the plastic strain at all integration points in the element exceeds the fracture strain.

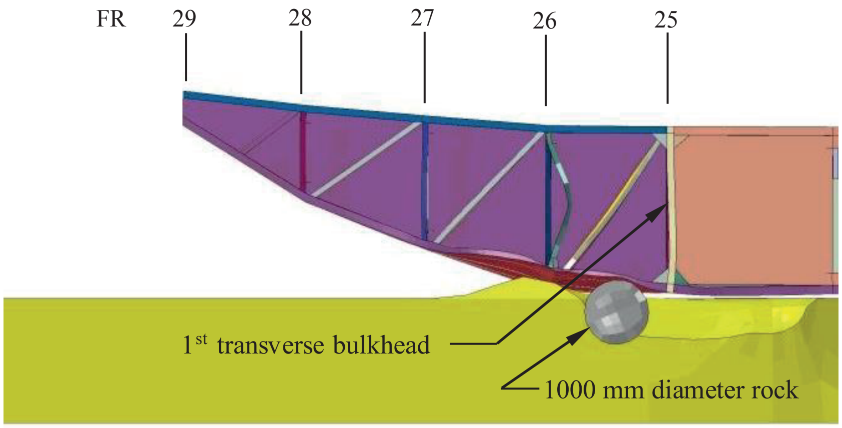
Grounding Simulation Results for Single Hull Construction

For the grounding event simulation of the single hull barge, the embedded object used was spherical and the initial size set equal to the maximum rock dimension (100 mm diameter) as determined from dredging operations. The mass of this rock is ~10 kg, as compared to the barge convoy with a mass of 10,514 tonnes, and has no effect on the movement of the barge and no energy absorbed as the rock is simply pushed into the soil. The dimensional size of the rock was increased proportionately by its diameter to 5x, 10x and 12x which is equivalent to an increase in mass by 125x, 1000x and 1728x for rock diameters of 500 mm, 1000 mm and 1200 mm respectively.

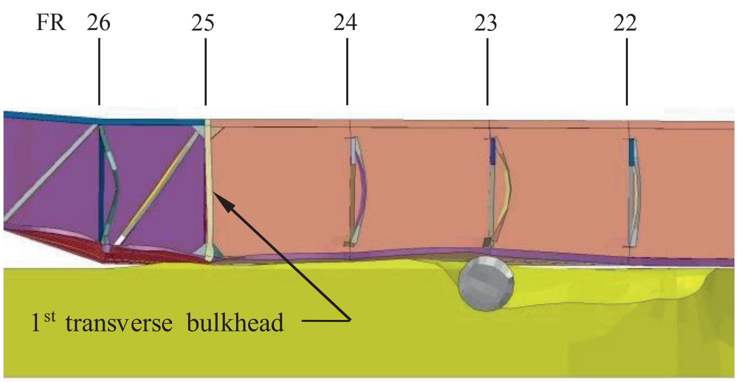
The damage accumulation on the outer hull plate of the single hull barge from a grounding event simulation with 100 mm and 250 mm diameter rocks demonstrates that there is no effect on the outer hull structure as the object was simply pushed into the soil. For the 500 mm, 1000 mm and 1200 mm diameter rocks, the small amounts of energy absorbed were determined to be 6 MJ, 16 MJ and 17 MJ respectively. The change in energy absorbed is of no consequence for larger rocks of increasing mass and is only dependent upon the shape and embedment of the rock in the soil. The larger embedded objects are at the extreme range of rock sizes and are unlikely to be found in the navigational channel as dredging operations would result in the removal of rocks of this size. Assuming a standard deviation (σ) of 100 mm for the mean rock size of 100 mm, the probability of occurrence for large embedded rocks within the channel with a minimum diameter of 500 mm (5σ from the mean) is 0.00003%. The larger rocks cause some damage and rupture of the outer hull plating with reliance on crack propagation for continued damage as the barge moves along over top of the rock. The Navigation and Vessel Inspection Circular (NVIC) No. 15-91[8] *(United States Coast Guard, 1994)* provides a methodology for calculating the critical crack length which was estimated to be 15 inches. The critical crack length, which may lead to crack propagation and rupture of the hull structure, is debatable.

The grounding event simulation for the single hull barge in contact with a 1000 mm diameter spherical object is shown in Fig. 10 where damage prior to the 1st bulkhead, damage between the 1st and 2nd bulkhead and damage after the 2nd bulkhead are illustrated in Fig. 10(a), (b) and (c) respectively. Most of the damage occurs over the first 0.6 seconds as illustrated by the plastic deformation (Fig. 11) with subsequent rupture occurring when the rock was beyond the first bulkhead. After rupture of the outer bottom plate, there is continuing plastification (small amount of energy absorbed) and damage to the outer bottom plate along the length. The model correctly represents the embedded object to soil interaction and the interaction between the barge, the embedded object and the soil. The most damage occurs upon initial contact with the bow, the most critical section, and the amount of damage may or may not exist based on the assumptions made (rock is not deformable; rock is more dense than assumed). Comparison of the damage accumulation to the barge from the 1000 mm to the 1200 mm diameter rock showed no real difference as rupture of the outer bottom plating also occurred in the vicinity of the transverse bulkhead and plastification continued over the length of the barge.

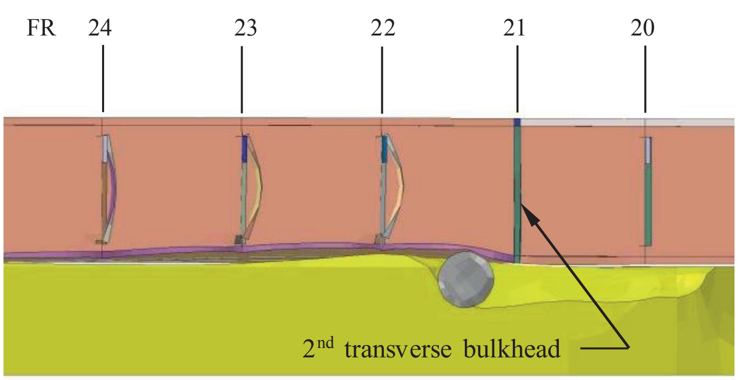
Fig. 10. Grounding Event Simulation with 1000 mm Diameter Spherical Rock



(a) Damage Prior to 1st Transverse Bulkhead, t = 1.2 s

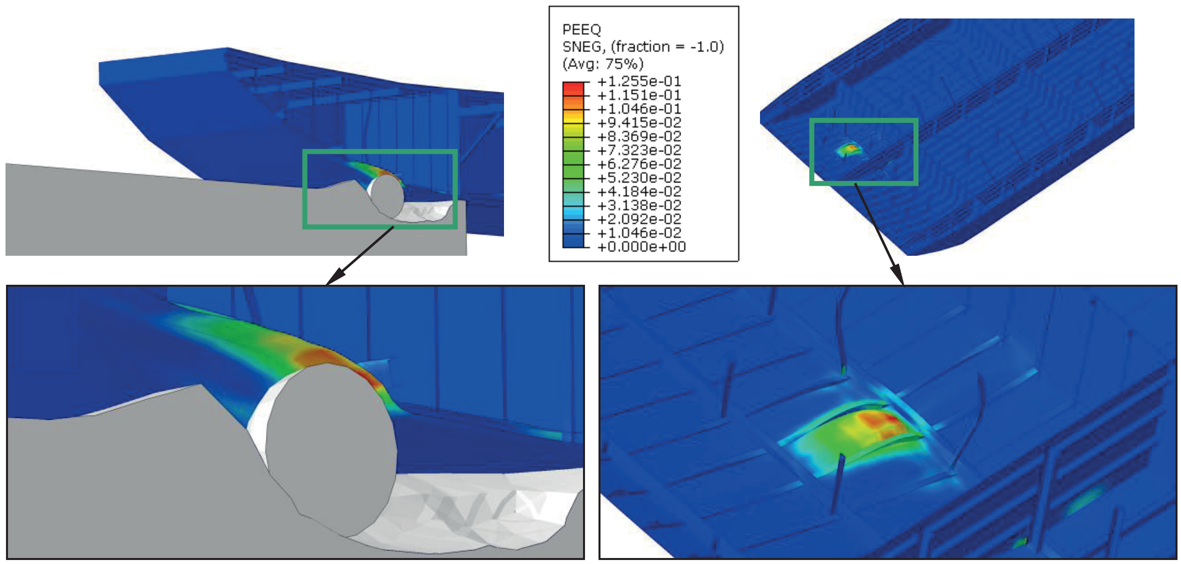


(b) Damage Between 1st and 2nd Transverse Bulkhead, t = 2.7 s



(c) Damage After 2nd Transverse Bulkhead, t = 3.6 s

Fig. 11. Plastic Deformation of Barge with 1000 mm Spherical Rock (t=0.6s)



The simulation demonstrates that the modeling assumptions are working correctly and that a deterministic definition of the rock size is appropriate where the embedded grounding object is selected based upon its interaction with the barge where rupture is caused to the double hull construction and no rupture to the SPS CDH.

Grounding Simulation for Double Hull and SPS CDH

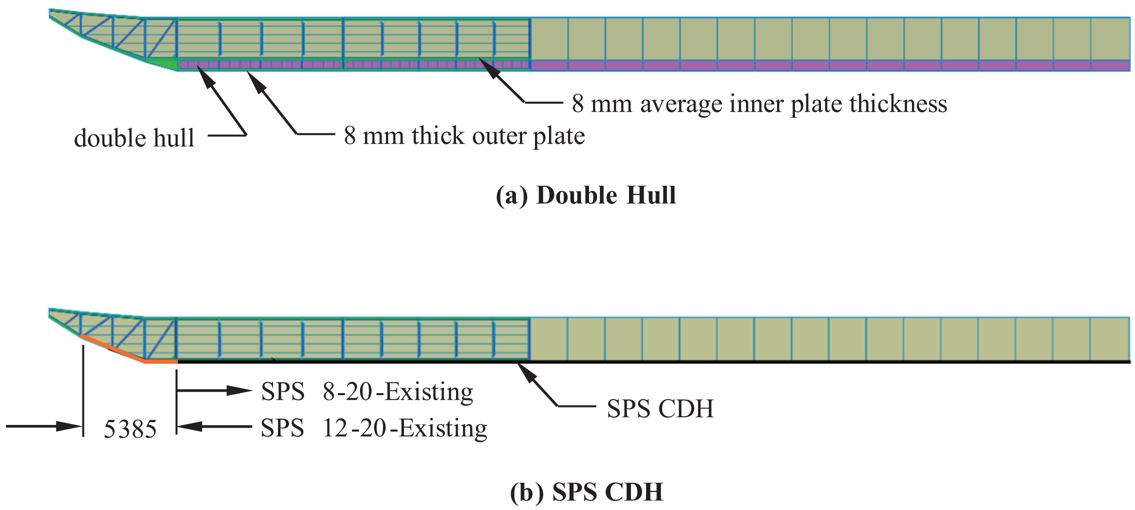
Geometry and Barge Model Description

Two barge configurations were modeled which include double hull construction and SPS CDH where both are based on the single hull construction. The double hull construction is based on an outer bottom plating thickness of 8 mm and internal framing structure that is added to the single hull construction. The double bottom construction is applied up to but not including the bow section, where a tapered transition is made from the cargo tank boundary to the initial section of the bow as schematically illustrated in Fig. 12a. The SPS CDH consists of the single hull construction with an SPS Overlay applied beneath the barge where a SPS 8 20 Existing (8 mm thick steel faceplate for outer bottom plating and 20 mm thick polyurethane elastomer core) is applied over the main body and a SPS 12 20 Existing is applied over a section of the bow region as schematically illustrated in Fig.12b. The grounding simulation study for the single hull barge identified that a localized area of robust construction in the bow region is required where initial contact with the embedded object is anticipated. The energy absorbed upon initial contact will be minimal as the robust construction in the bow region will allow the barge to deflect upwards and ride over top of the embedded object. Recognizing that the energy absorption will be minimal, the SPS CDH design with two different faceplate thicknesses has been tailored to mitigate the damage to the outer hull structure from a grounding event. Corresponding drawings for the SPS CDH are provided in Appendix A.

Embedded Grounding Object

The shape, amount of embedment, and orientation of the embedded grounding object was selected based upon its interaction with the barge where rupture was caused to the double hull construction but not to the SPS CDH. The prism-block shaped object illustrated in Fig. 13 was arrived at empirically, was easily modeled with artificial properties, contains angular profiles, and has an embedment depth that was easily modified. The

Fig. 12. Double Hull and SPS CDH Barge Model



mass of the embedded grounding object, which is more than 2 times larger than the largest rock tested in the grounding simulation for the single hull barge, was oriented to cause the maximum resistance with the soil such that the rolling resistance of the embedded grounding object is increased allowing the barge to ride over top. The embedment depth of the embedded grounding object used for the grounding simulations is 800 mm.

Fig.14 illustrates the rupture of the outer hull plate in a single hull barge and similar damage from a corresponding grounding simulation model of a single hull barge. The damage to the outer hull plate is consistent with damage associated with other man-made embedded objects such as a spud where local rupture of the single hull is highly localized in the vicinity of the embedded object. The lateral extension as the object passes over the 1st transverse bulkhead and tunneling are again localized and associated with contact with the embedded object as it is driven into the soil. A detailed description of the grounding simulation results for the double hull construction and the SPS CDH is presented in the following section.

Fig. 13. Embedded Grounding Object

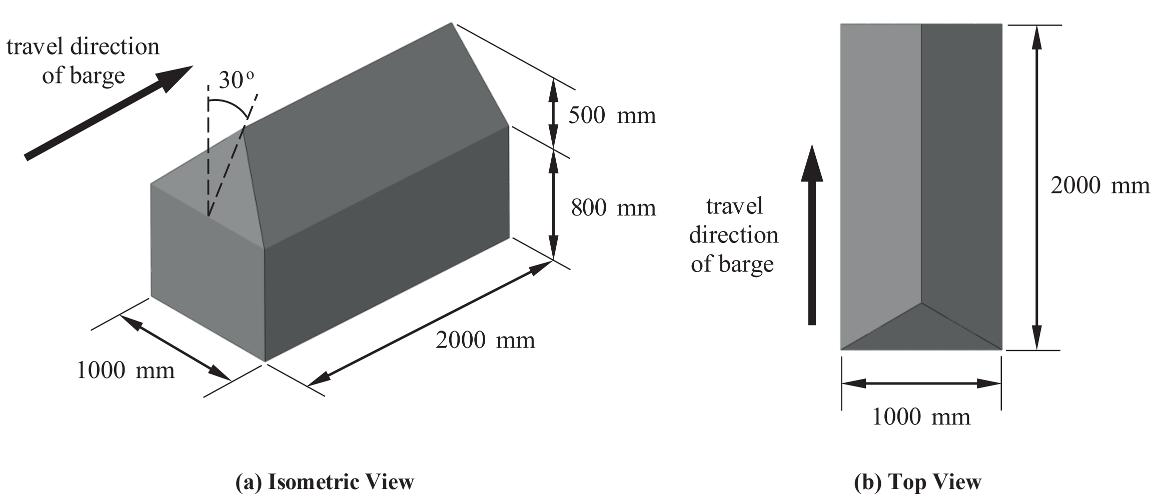
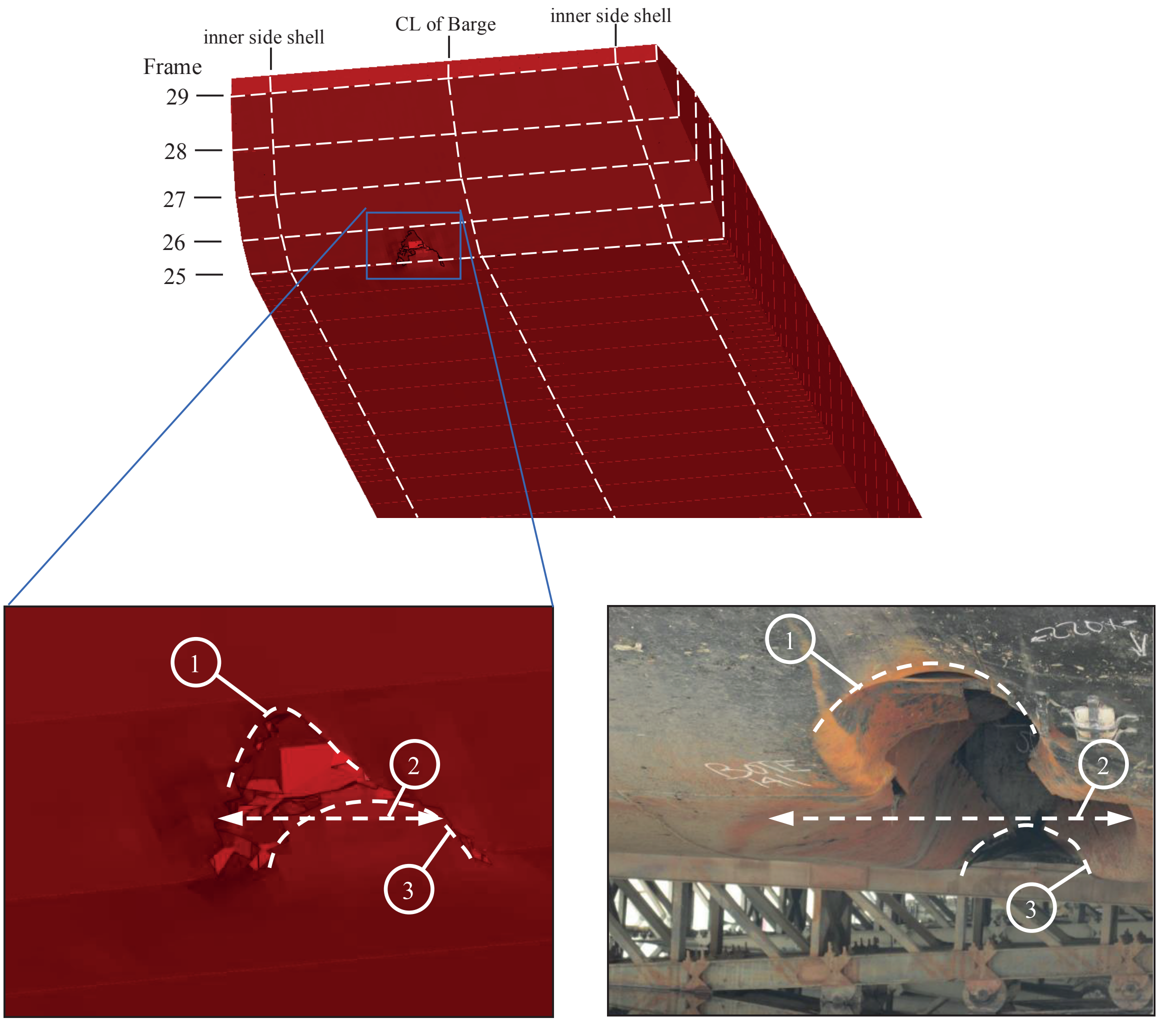


Fig. 14. Rupture of Outer Hull Plate



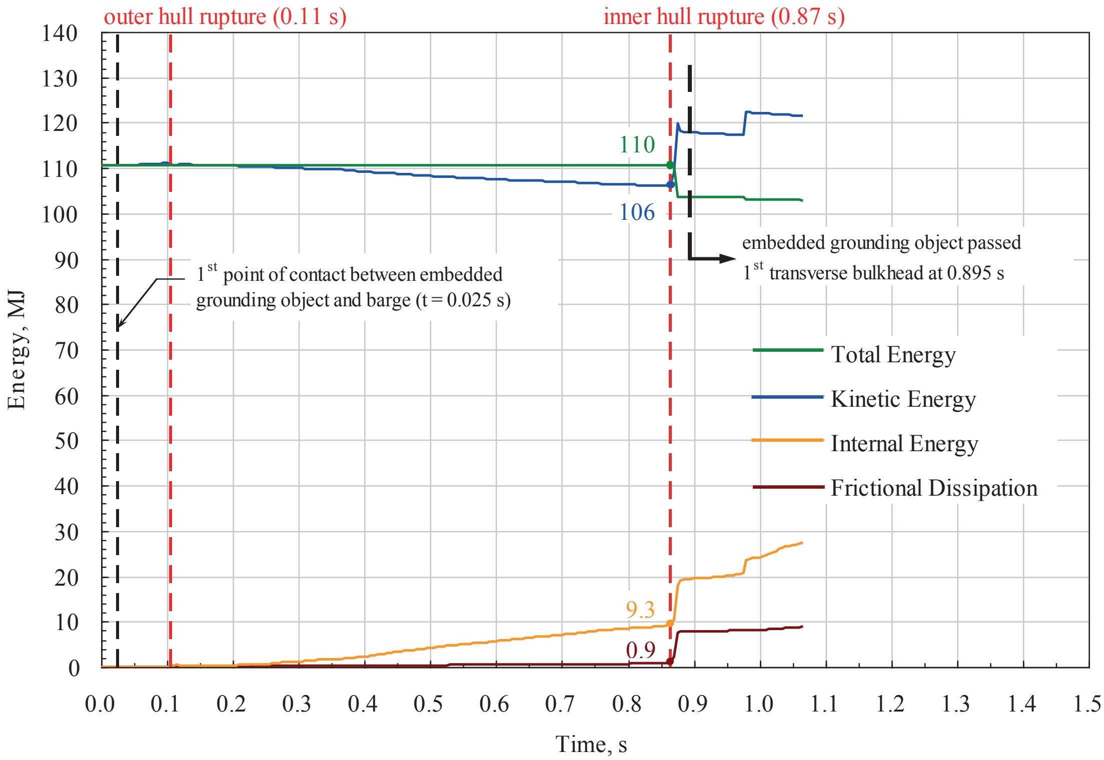
Double Hull Tank Barge **Single Hull Tank Barge**

1. Initial local rupture of outer hull plate; 2. Lateral extension of rupture; 3. Tunneling

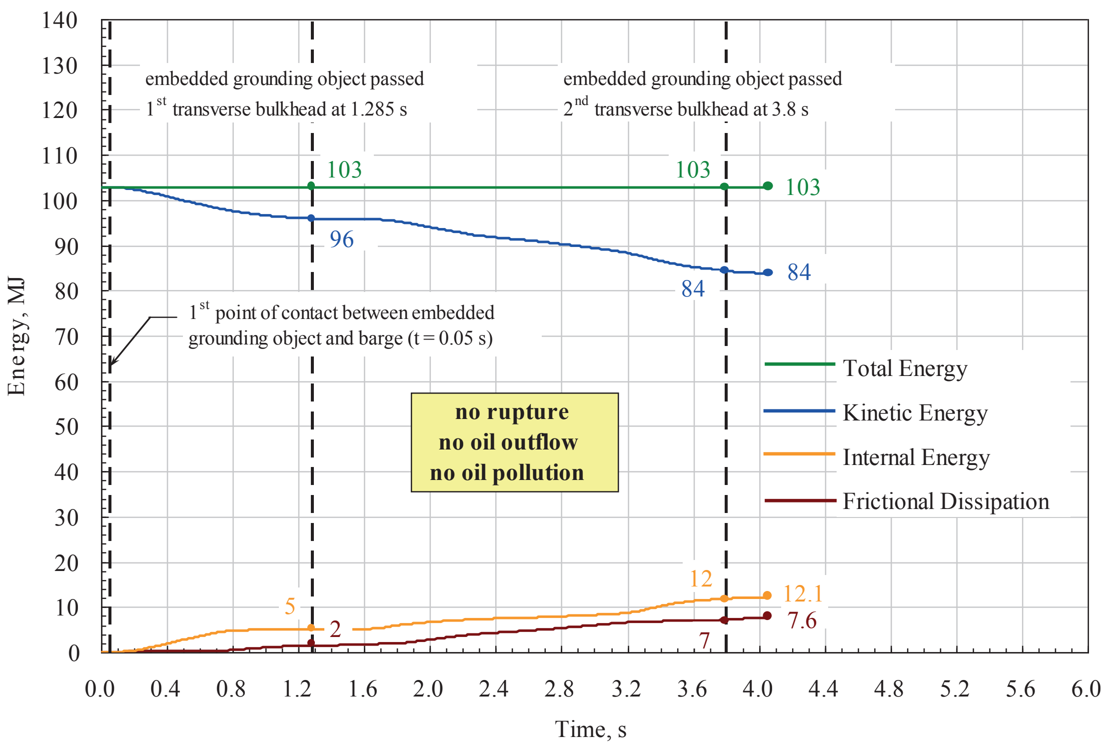
Grounding Simulation Results for Double Hull and SPS CDH Construction

For the grounding event simulation of the double hull construction and SPS CDH, the performance is summarized in the energy curves illustrated in Fig. 15. As shown in the graphical energy plots, the rupture of the outer hull for the double hull occurs very quickly upon contact with the embedded object (0.11 seconds) which manifests itself into the rupture of the inner hull when the embedded object crosses the first transverse bulkhead (0.87 seconds). Subsequently, the energy curves have less meaning as the elements are highly distorted and become disassociated with the existing barge body. The corresponding graphical energy plot for the SPS CDH illustrates that the initial contact is absorbed and the barge rides over top of the embedded object with no rupture, no oil outflow and no oil pollution. The total energy absorbed is relatively small even for an object with more than twice the mass but similar resistance and with similar energy absorbed as for the spherical embedded object with a 1200 mm diameter. The energy absorbed during the grounding event is not the key design driver, but simply the amount of damage.

Fig. 15. Energy vs. Time



(a) Double Hull Construction

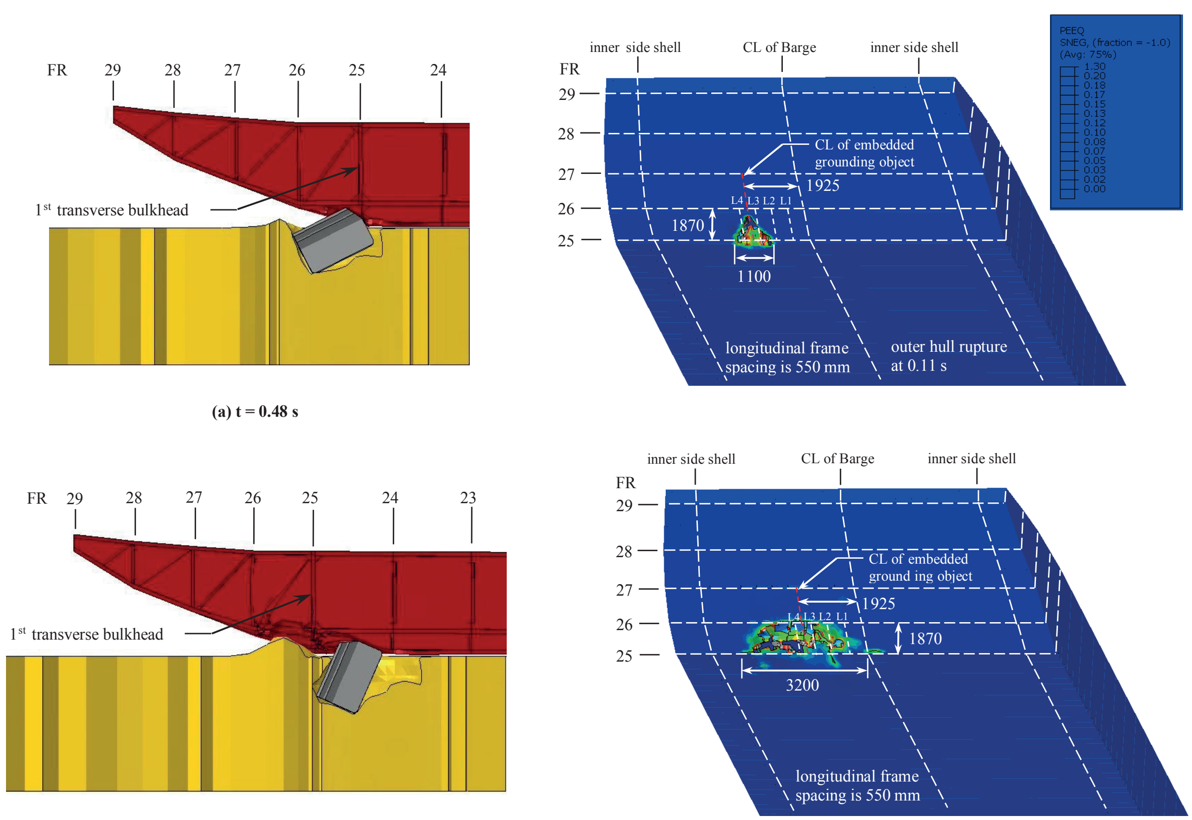


(b) SPS CDH

The grounding simulation results are best described through a series of illustrations which show the embedded object with respect to the barge and the plastic strain as a function of time. The corresponding images are given in Fig. 16 and Fig.17 for the double hull construction and SPS CDH respectively. For the double hull construction, rupture of the outer hull occurs at the point of contact while the inner hull ruptures as the embedded object passes the first transverse bulkhead. Interaction of the embedded object and the soil causes the outer hull plate to rupture over a single frame plus half of a frame on each side. The damage grows throughout the time history, including damage to the internal frame structure. The rupture of the hull plating increases the possibility of propagating cracks associated with this type of ground event (speed, large mass and little or no reduction in energy) and would lead to oil outflow and oil pollution. The largest extent of damage was identified at the end of the bow and at the transverse bulkheads which are hard spots. Initial rupture and damage may occur sooner and be more severe than predicted by the grounding simulation model as the thin tapered section at the end of the bow constructed with slotted welds are not ideally connected to the inner bottom as in the model.

Fig. 17 illustrates the extent of damage to the SPS CDH which is significantly less than for the double hull construction. The damage is spread over a larger width as the load is distributed and there is no growth in the damaged area. The embedded object is struck and the barge is deflected upwards and rides over top of the embedded object and continues to move forward. The maximum energy absorbed is similar to that for the double hull construction. It is anticipated that the barge convoy would come to rest after damage to the 3rd barge based on the results from the graphical energy plots. The results demonstrate that rupture is prevented for the specified grounding event and therefore there is no oil outflow and no oil pollution. The SPS CDH construction demonstrates that it must be equivalent or better

Fig. 16. Grounding Event Simulation Results, Double Hull Construction

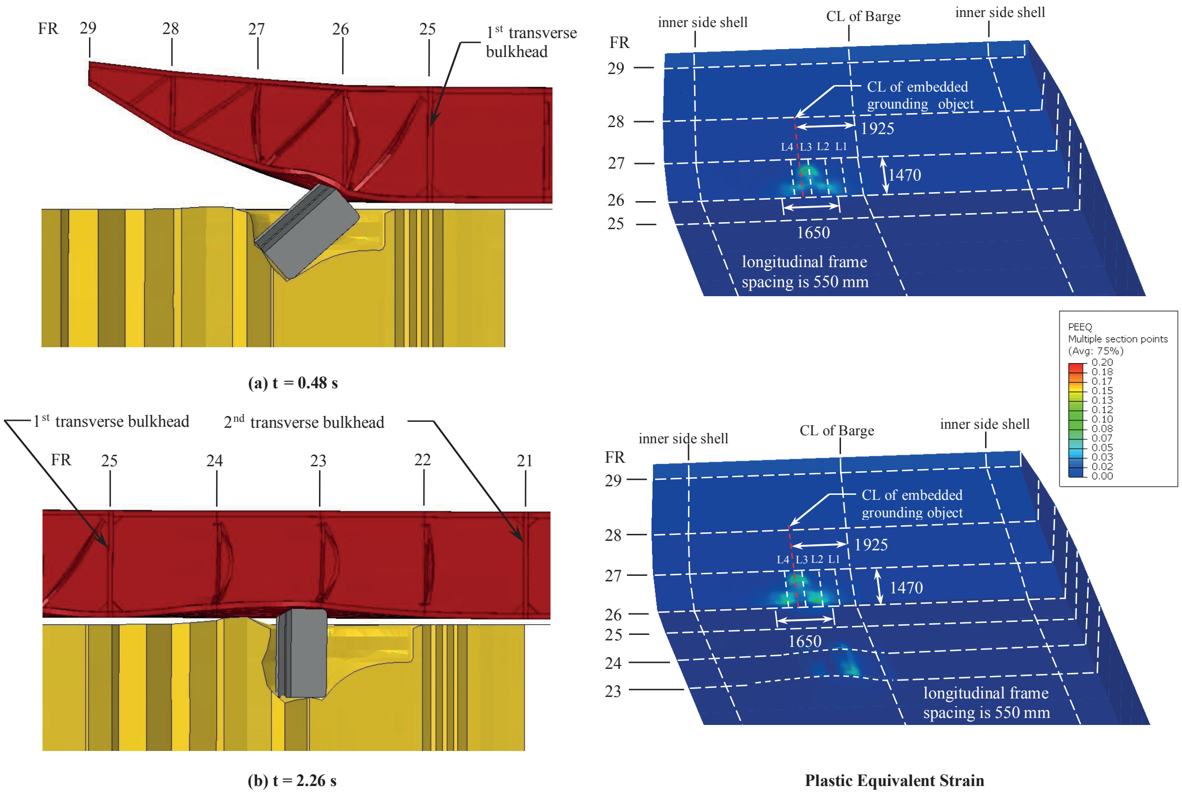


(a) t = 0.48 s

(b) t = 1.08 s

Plastic Equivalent Strain

Fig. 17. Grounding Event Simulation Results, SPS CDH



than a double bottom construction for protection against oil pollution.

Inspection, Maintenance and Damage Stability

Inspection and Maintenance

Part 7 of the ABS Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways[1] state that for inspections after construction of the vessel, the ABS Rules for Survey After Construction (Part 7) is to be referenced. Some of the relevant clauses within these rules regarding inspection are given below.

- Chapter 2, Section 3 – Survey Intervals
- Chapter 3, Section 1 – Requirements for Internal Examinations of All Vessels
- Chapter 3, Section 4, Clause 1.3 – Thickness Measurements
- Chapter 4, Section 1, Clause 1(v) – All Vessels

"Side and bottom plating externally. The shell plating is to be examined for excessive corrosion, or deterioration due to chafing or contact with the ground and for any undue unfairness or buckling. Plate unfairness or other deterioration which does not necessitate immediate repairs is to be recorded."

The SPS CDH construction allows these inspection processes to be completed efficiently within a safe and easily accessible environment.

The key difference between double hull construction and SPS CDH for inspection and maintenance is that void spaces exist in both the double bottom and wing tanks for the double hull construction and are restricted to the wing tanks only for SPS CDH construction. The wing tank structure is common to both. As part of the inspection process, the thickness measurements are to be made on plating from within the cargo tank and possibly to the outer hull plating from outside depending upon where corrosion is more likely to occur. The double bottom construction has the following negative impacts associated with the void space created by the double bottom construction:

- additional surface area requiring inspection
- problems to ventilating and expelling gas from the double bottom spaces make inspection and maintenance difficult and dangerous
- difficulty to access confined spaces
- more complex structure that requires coating and ongoing maintenance
- if ballasting is required, it is easier for sediments to become trapped whereby corrosion of the hull plating may go undetected; ballast pumps would be required to remove ballast water
- safety management system is an important aspect of the International Safety Management (ISM) Code; the vessel operator must develop maintenance procedures specific to their vessel; inspection and maintenance operations and the risk associated with these activities are reduced and mitigated for SPS CDH construction compared to double hull construction

The SPS CDH construction mitigates the negative consequences associated with corrosion, inspection and maintenance in the 610 mm void space of the double bottom construction as there is no void space between the inner and outer skin of the hull structure.

The steel faceplates and polyurethane core used in SPS CDH are 100% recyclable. The components are separated. The steel is recycled normally and the polyurethane core is broken down into small pieces using an industrial waste shredder and re-used as rubble core (similar to aggregate) in new composite sandwich plates.

Damage Stability

For conventional double bottom construction, the responsibility for damage stability verification is placed on the designer of the vessel. Although Part 3, Chapter 2, Section 1, Clause 19.1.1 of the ABS Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways[1], as stated below, refers to stability when tanks are being filled or emptied, it is assumed that it is equally applicable to the stability when damage occurs that may cause flooding of the double bottom/wing tanks.

"It is assumed that those responsible for the design of the vessels have assured themselves that the subdivision is such as to ensure sufficient stability in service when the tanks are being filled or emptied."

For SPS CDH construction, since it was demonstrated that there is no rupture and no oil outflow for a specified grounding event, there will be no flooding of the cargo space and therefore a damage stability assessment is not required.

Comparison of Benefits between SPS CDH and Double Hull Constructiony

The SPS CDH design provides a double bottom structure that is equivalent to or better than double hull construction in protecting the environment against oil outflow and oil pollution and provides significant economic benefits which are described in this section. It is simple and fast to construct and requires no changes to cargo handling systems or inspection and maintenance cycles. SPS CDH is approximately 2.0% lighter than the double hull construction and allows 1% more volume of cargo to be transported. The key commercial drivers that impact the costs and time associated with using SPS CDH for the barge conversion include the following: (a) reduced installation costs; (b) reduced installation time; (c) increased revenue opportunity; and; (d) reduced inspection/ maintenance cycles. These items are discussed below and were determined from a study of a typical fleet of inland waterway barges.

- reduced installation costs: reduction in the weight of steel, number of steel pieces, weld length, surface area and coatings result in cost savings of approximately 5% (including materials and labour).
- reduced installation time: estimated time to complete a SPS CDH conversion is 28 days compared to 90 days for a double hull

conversion (69% reduction in schedule). Difficulty accessing and working in confined spaces affect the time to complete the conversion. Double bottoms must be vented and made gas free to allow welding operations to proceed which impacts schedule.
- increased revenue opportunity: based on installation times described above, 12 conversions per year can be completed using SPS CDH and 4 conversions per year with double hull construction; the barge rate for converted barges is approximately 20% higher than for single barges and having a greater number of barges available for a given year provides a considerable economic benefit.
- reduced inspection/maintenance cycles: annual maintenance and inspection costs are reduced as the number of steel pieces (92% reduction), weld length (79% reduction) and coated surface area (71% reduction) are less for a SPS CDH design. Significant increases in steel pieces and weld length leads to more connections that are prone to fatigue and weld failure. Due to lack of access, work must be conducted in confined spaces that may lead to a lesser quality in workmanship and weld quality which is equivalent to increased maintenance cost. Note, there is no access in the bow transition zone for the double hull construction and this section will not be inspected. It is completed with slotted welds from one side and suffers from localized damage to the coatings.

The SPS CDH design provides a 15% overall cost saving compared to double bottom construction for a typical barge fleet with added cost advantage accrued over the life of the barges.

Summary and Conclusions

MARPOL regulations stipulate that all single hull oil carrying barges, designed to meet ABS Rules for Building and Classing Steel Vessels for Service on Rivers & Intracoastal Waterways[1], must be made of double skin construction or modified by an alternate construction provided that the construction ensures an equivalent level of protection against oil pollution. The conventional solution consists of adding a double hull structure to the cargo tank region of a single hull barge in accordance with ABS Rules. However, the rules do not provide a structure which is consistent with a specified grounding event. The specified grounding event is based on rupture and not on energy absorption where a small amount of energy is absorbed relative to the input (kinetic) energy. Furthermore, although the double hull construction meets the MARPOL regulations, the greatest protection is not provided where the initial impact is anticipated (transition area in the bow section).

A grounding simulation study for single hull barge construction was conducted to: ensure the simulation of grounding events is a reasonable representation of the actual conditions; verify the soil characteristics and behaviour; evaluate the effect of different embedded objects. The study was based on a barge convoy consisting of 8 tank barges and a push tug with a total mass of 10,514 tonnes and traveling with a maximum velocity of 16 km/hr. The navigable channel is dredged regularly and therefore the conditions of the river bed are well known. The embedded objects used consisted of a rock with a diameter of 100 mm, as determined from dredging operations, up to a maximum rock size with a diameter of 1200 mm (1728 times the mass of the 100 mm diameter rock). The mechanism of grounding events is extremely complex and there are no papers or few records of grounding reports that can be used to expand the knowledge base and confirm the modeling approach. In an effort to simplify the problem and simulate the grounding events, a number of modeling assumptions were made.

Based on the experience gained from conducting a grounding simulation study for single hull barge construction, a comparative grounding simulation study for the double hull construction and SPS CDH construction was completed. The double hull barge was subjected to a specified grounding event which causes rupture of both the inner and outer hull of the double bottom construction to occur resulting in oil outflow and oil pollution. The SPS CDH was designed such that after the initial contact from the specified grounding event was absorbed, the barge rides over top of the embedded object with no rupture, no oil outflow and no oil pollution therefore not only satisfying but exceeding the criterion as stipulated in MEPC.110 (49)[4]. If the grounding event is not severe, it is possible that the damage may be such that repair is not required and that the barge may be subject to and resist future grounding events.

The challenges associated with inspection and maintenance procedures required for double hull construction, where void spaces exist in both the double bottom and wing tanks, are advantageously mitigated for SPS CDH construction. The SPS CDH construction allows inspection and maintenance procedures to be conducted with less risk and more efficiently within a safe and easily accessible environment.

Damage stability verification is required for double hull construction as flooding may occur in the double bottom/wing tanks. For SPS CDH construction, since it was demonstrated that there is no rupture and no oil outflow for a specified grounding event, there will be no flooding of the cargo space and therefore a damage stability assessment is not required.

A detailed assessment of a typical barge fleet indicates that there is a 15% cost saving with added cost advantage accrued over the life of the barges.

IE has demonstrated that the SPS CDH alternative design provides a bottom hull structure that is equivalent to or better than double hull construction in protecting the environment against oil outflow and oil pollution due to a grounding event.

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Methodological Proposal for the Identification of an Interregional Project Portfolio for the Economic Development and the Exploitation of the Riverine Vocation of Colombia

Propuesta Metodológica para la identificación de un Portafolio de Proyectos Interregional para el Desarrollo Económico y el Aprovechamiento de la Vocación Fluvial de Colombia

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Abstract

The Colombian riverine system is composed by a 27.725km water network distributed in the four major basins (Magdalena, Amazonas, Atrato, Orinoco) along the country. 73.1% of the system can be considered as waterways. However instead of leveraging the potential for the exploitation of this natural resource and the promotion of a riverine transportation system which can impact neighboring populations in social aspects such as health and education, in Colombia the priority is focused to road transportations systems. The National Government, which has adopted the challenges for the sustainability of the planet, has accepted the Sustainable Development Goals (SDG) promulgated by the UN and at the same time has linked the iniciative to its 2014 – 2018 National Development Plan. The possibility of connecting the promotion of its riverine vocation and capabilities for solving known socioeconomic needs motivate the creation of this methodological proposal that is driven by the identification of an interregional project portfolio that can be the starting point for closing the diagnosed gaps. At the same time it also makes the accomplish. Went of the goals established by the 2030 Agenda for Sustainable Development, defined by United Nations, feasible.

Key words: SDG, Project Portfolio, National Development Plan, Hydrographic Basins.

Resumen

El sistema fluvial colombiano está compuesto por una red hídrica de 27.725 km distribuidos en cuatro grande cuencas (Magdalena, Amazonas, Atrato, Orinoco) a lo largo del territorio nacional. De esta red el 73.1% es clasificado como navegable. Sin embargo a pesar del potencial que se tiene para el aprovechamiento del recurso natural y el fomento de un sistema de transporte hidroviário que impacte positivamente a las poblaciones ribereñas en temas sociales como salud y educación, en Colombia la prioridad se encamina al modal de transporte terrestre. El Gobierno Nacional adoptando los nuevos desafíos para impulsar la sostenibilidad del planeta, se ha acogido a los Objetivos de Desarrollo Sostenible (ODS) promulgados por la ONU y a su vez los ha enlazado con sus estrategias contempladas en el Plan Nacional de Desarrollo 2014 – 2018. La posibilidad de enlazar el fomento de la vocación fluvial de los ríos del país y sus capacidades de solventar las necesidades socioeconómico conocidas, motivan la creación de una propuesta metodológica orientada a la identificación de un portafolio de proyectos interregional que se constituya en el punto de partida para la solución de las brechas diagnosticadas al tiempo que se cumplan con las metas establecidas por la Agenda 2030 para el Desarrollo Sostenible definidas por las Naciones Unidas.

Palabras claves: ODS, Portafolio de proyectos, Plan Nacional de Desarrollo, Cuencas hidrográficas.

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Introduction

This paper is intended to present a methodological proposal that allows the identification of a portfolio of interregional projects, focused on the economic development and the exploitation of the fluvial vocation of Colombia.

Motivated by the potential represented by the hydrographic network for the development of the country and the fulfillment of the goals set out in the Agenda 2030 of the United Nations for the sustainability of the planet, this proposal constitutes a contribution to the nation, its Entities, including stakeholders from the public or private sector, for the formulation and structuring of projects and portfolios that can be implemented synergistically between the regions of the national territory.

The initial diagnosis of the Colombian river transport system and the connection between the National Development Plan and the sustainable development objectives raise the need for the generation of this methodological proposal.

The River Transport System in Colombia

The River Transport System in Colombia is constituted by 27,725 km according to the last update of statistics of the sector *(Ministry of Transport of Colombia, 2016)*.

73.1% are navigable routes (18.225 km) and 26.29% are the non-navigable waterways (6,500 km).

This network is conformed by four large hydrographic basins, belonging to the Magdalena, Atrato, Orinoco and Amazon rivers.

The distribution of the fluvial arteries by the four basins[1],[2] of the hydrographic system is shown below in Table 1.

If the infrastructure available for road and rail modes is taken into account, the fluvial mode represents only 10.52% of the national total (Fig. 1).

The fluvial infrastructure available in the year 2015[3] allowed 2,460,460 passengers and 3,524,000 tons of cargo to be transported, of which the Magdalena River contributed 53.65% in the transport of cargo (1,890,467 tons) and 54.85% in the transport of people (1,349,503 passengers).

Comparing the number of national passengers transported by land in the year 2015, with those mobilized through the waterways, it is evident that the road modality has predominance in the Colombian system. Table 2.

The relationship between the two compared modes shows that the road modality exceeds approximately 77 times the number of passengers transported by the waterways of Colombia. In other words, the

[1] The Main tributaries by river basin are: A. Magdalena Basin: Magdalena, Canal del Dike, Cauca, Nechí, Cesar, Sinú, San Jorge. B. Atrato Basin: Atrato, San Juan, Baudó, C. Orinoco Basin: Orinoco, Meta, Arauca, Guaviare, Inírida, Vichada, Vaupés, Unilla. D. Amazon Basin: Amazonas, Putumayo, Caquetá, path.

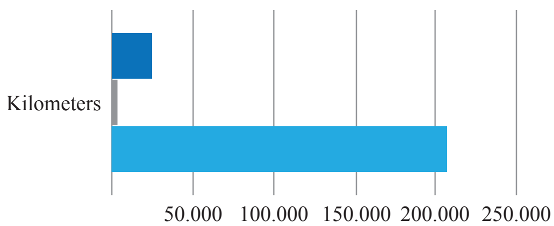
[2] The navigable and non-navigable sections of the affluents to the different hydrographic basins of Colombia can be consulted in the "Transport in Figures" document of the Ministry of Transport.

[3] (Ministry of Transport of Colombia, 2016)

Table 1. Distribution of the Colombian river network by watersheds

Hydrographic Basin	Navigable Lenght			No navigable lenght (km)	Total lenght (km)
	Major permanent	Transitory	Minor permanent		
Magdalena	1.188	277	1.305	1.488	4.258
Atrato	1.075	242	1.760	1.358	4.435
Orinoco	2.555	1.560	2.621	2.161	8.897
Amazonas	2.245	2.131	1.266	1.493	7.135
Total					24.725

Fig. 1. Distribution of the Transportation Infrastructure in Colombia. Road, rail and river modalities



	Kilometers
Inland modal	24.725
Railway modal	3.529
Road modal	206.727

Table 2. Number of domestic passengers transported in Colombia during 2015

National passengers	**Road mode**	188.836.000
	Air mode	23.116.340
	Inland mode	2.460.460
	Rail mode	458.619

river mode of passenger transport in Colombia represents just 1.3% of those transported by land.

The data presented in Fig. 1 and Table 2 show the predominance of the road mode in the Colombian transport grid.

In consequence to the above, the fleet of road vehicles is the most important in the country with a total of 12,119,782 transport units. Table 3.

Table 3. Colombian transport fleet

Road Mode	**Vehicles**	12.119.782
Rail Mode	**Locomotive**	108
	Railway carriage	3.678
Inland Mode	**Tugs**	173
	Barges	557

Based on this information it is ratified that in Colombia there is an urgent need to leverage fluvial development.

Although the country has 18,225 km of navigable rivers distributed in the Magdalena, Atrato, Orinoco and Amazon basins, it is still not possible to say that Colombia is a fluvial nation. However, it has a vocation to become a fluvial country and to modify the current distribution of the national transport grid.

According to the data presented, in 2015, in just 1.092 km of navigable sections of the Magdalena River, more cargo and passengers were transported than in the remaining 17.133 km available from the national total distributed over the four watersheds. This situation shows that the fluvial development of Colombia has concentrated in the Magdalena River, which represents only 6.37% of the total navigable rivers, since it has the potential to connect the interior of the country with the north coast.

This panorama of the current river system can be regarded as a competitive disadvantage for Colombia. However, it marks a starting point for an improvement opportunity that constitutes rivers as the new focus of economic and social development of the country, through the promotion of the multimodality, with the respective North-south and east-west interconnection, where the productive development centers of the country can communicate with the export ports and where marginalized populations located in regions of low connectivity can have access to the systems of education, health and transport in the country.

The present diagnosis and characterization of the Water road system is constituted as an important information input that supports the generation of interregional projects oriented to promote economic and social development through the use of Colombia's current fluvial vocation.

In this sense, any new project aimed at the fluvial sector of Colombia should focus on the guidelines given by the United Nations for sustainable development in the face of the global strategic scenario defined for 2030, where the eradication of poverty, the protection of the planet is sought to ensure prosperity.

Likewise, these initiatives must be aligned with the current Colombian national development Plan, which is based on three fundamental pillars: peace, equity and education.

For this reason, we provide the background of the Agenda 2030 for the Sustainable Development and the 2014 – 2018 Plan defined by the National Planning Department.

Agenda 2030 for Sustainable Development

Agenda 2030 for sustainable Development has its background in the year 2000 with the formulation of the Millennium Development Goals (MDGs), which were agreed upon by 189 UN member countries. This commitment is focused on achieving the challenges to eradicate poverty, achieving universal primary education, gender equality, reducing infant and maternal mortality, combating the advancement of HIV/AIDS, the sustainability of the environment, and also the promotion of a global partnership for development *(United Nations Development Programme-UNDP, 2015)*.

These objectives were divided into a set of 18 quantifiable targets by the definition of 58 indicators, with the maximum deadline for accountability set for 2015.

The measurement of the MDG showed that these objectives were a global success, however, the need to work harder to respond to the immense challenges that have not yet been solved was also clear, such as poverty, education, the environment and peace.

Aware of these challenges and their local needs, Colombia proposed at the Rio + 20 World Summit [4](United Nations Conference on Sustainable Development), the so-called Sustainable Development Goals (SDGs) with an environmental approach aimed at the protection of bio-diversity.

On September 27, 2015, the Agenda 2030 for Sustainable Development was signed at the United Nations Headquarters in New York[5], as an action plan for the people, the planet, prosperity, peace and alliances based on a spirit of global solidarity focused on the needs of the poorest and most vulnerable in society with the collaboration of all signatory countries.

[4] Summit held in the city of Rio de Janeiro – Brazil.

[5] 193 member countries of the United Nations system signed and agreed on the commitments acquired through the new Sustainable Development Goals (ODS).

Fig. 2. Sustainable Development Goals – SDG. Source: Document: "Objectives of Sustainable Development, Colombia – tools of approximation to the Local context"

17 new objectives are agreed upon (Fig. 2) together with 169 goals that reflect the commitments made with the MDGs in the year 2000. In order to achieve what hasn´t been accomplished yet a new term of 15 years has been established[6].

Colombia The National Development Plan 2014 – 2018 and the SDGs.

With Decree No. 280 of February 18, 2015, by which the High-Level Interinstitutional Commission for the enlistment and effective implementation of the Post-2015 Development Agenda and its Sustainable Development Objectives (SDG) was created[7], Colombia becomes the first country attached to the United Nations to align and articulate its Development Plan with the SDGs.

In this way the "All together for a New Country" plan in force from 2014 – 2018 was created to contemplate the objectives and strategic goals oriented to the generation and strengthening of the conditions necessary to build a society in peace, equality and educated.

To achieve the articulation between the Development Plan and the SDGs, Colombia is supported by the National Planning Department (DNP), that defined four steps to incorporate these objectives into the Territorial Development Plans (TDP). Fig. 3.

Fig. 3. Steps to integrate SDG with TDP in Colombia

The DNP proposes a process of integration that begins with the articulation of the government program with the SDGs, it then gives importance to the data by collecting and analysing information on the current state of the territorial entities based on the sustainable development objectives.

Having completed the diagnosis, the next step is the definition of indicators and the programming of the goals to be fulfilled in the Territorial Development Plan (TDP) within the framework of the SDGs:

The process is culminated with the identification of the sources of the resources from the different levels of government to contribute to the compliance with the SDGs by the department or municipality. With regard to this context, it is possible to infer that there is a commitment on the part of the Colombian State to comply with Agenda 2030 for Sustainable Development.

Continuing from this summary of the background of the SDGs and their integration with national development policies, the following proposes a methodology oriented to the identification of a portfolio of interregional projects focused on the fluvial vocation of the country and its potential to generate socio-economic transformation according to the needs of the population.

Methodology for the Identification of the Portfolio of Sustainable Projects Focused on the Fluvial Sector

Aware of the natural richness offered by the Colombian river system and the needs that must be addressed in order to achieve the goals posed by SDG in the country, the Science, Technology and Innovation Management (GECTI) of Cotecmar[8], as the leader and director of the scientific and technological programs, projects and activities oriented to the fulfillment of its R + D + i Policy[9],

6 (United Nations, 2015)
7 (Republic of Colombia, 2015)

8 Science and Technology Corporation for the development of the Naval, Maritime and Fluvial Industries.
9 Research + development + innovation

prepared and proposed the following methodology to identify an interregional portfolio of projects aimed at generating socioeconomic development.

This methodology has been developed based on the conceptualizations studied from the UN *(United Nations Development Programme, 2009)*, the generic model for organizational capacity development *(The Model of Organisational Capabilities Development, 2014)*, The generic process for capacity-based planning *(The Technical Cooperation Program Joint Systems and Analysis Group Technical Panel 3, 2004)*As well as the Project Management models and standards *(López Ruiz, 2015)*.

The methodology consists of 6 highlighted processes:

1. Understanding the Nation's Strategy.
This process is aimed at consulting and assimilating the Current National Government Development Plan[10]. This seeks to obtain clarity on the mission and vision of Colombia regarding its guidelines for development initiatives[11] and how they are articulated with the SDGs. (Fig. 4).

2. Identification of Territorial Needs.
Having assimilated the national strategy, the next stage is to identify the territorial needs that exist in the different departments. The Territorial Development Plans (TDP) should be taken as the information input.

[10] This plan corresponds to the 2014 – 2018 term and has been called "All together for a New Country".
[11] (National Planning Department-DNP, 2015).

With the TDPs it is necessary to study the diagnosis of each department in relation to all its socioeconomic issues, to identify the baseline of needs and the gaps that need to be corrected, as well as the goals and indicators that have been proposed by the governor´s offices to enforce the development plans. This process will provide an outlet for identifying needs that have potential for the development of territorial capacities in the country. (Fig. 5).

3. Categorize needs
This process has been devised to classify the needs with potential to generate territorial capacity, according to the sectors[12] and their relationship with the SDGs. (Fig. 6).

4. Evaluate and select needs by category
On the needs have been categorized they are sent for evaluation and selection.

The first evaluation is based on the potential that these needs have to generate capacities that promote the development of the river sector and the impact they can have on Education, health and transportation.

According to the foregoing, it is evident that the methodology gives explicit priority to only 3 sectors out of the 18 defined by the governor´s offices[13].

[12] 1. Agricultural, 2. Drinking water and basic sanitation, 3. Environment 4. Vulnerable groups response, 5. Prisons, culture, 6. Sport and Recreation, 7. Community Development, 10. Education 11. Municipal equipment, 12. Institutional strengthening, 13. Justice and Security, 14.Disaster Prevention and Response, 15. Promotion of development, health, 16. Public services, 17. Transport 18.Housing.
[13] The same as 12.

Fig. 4. Process 1-inputs and outputs

Fig. 5. Process 2-inputs and outputs

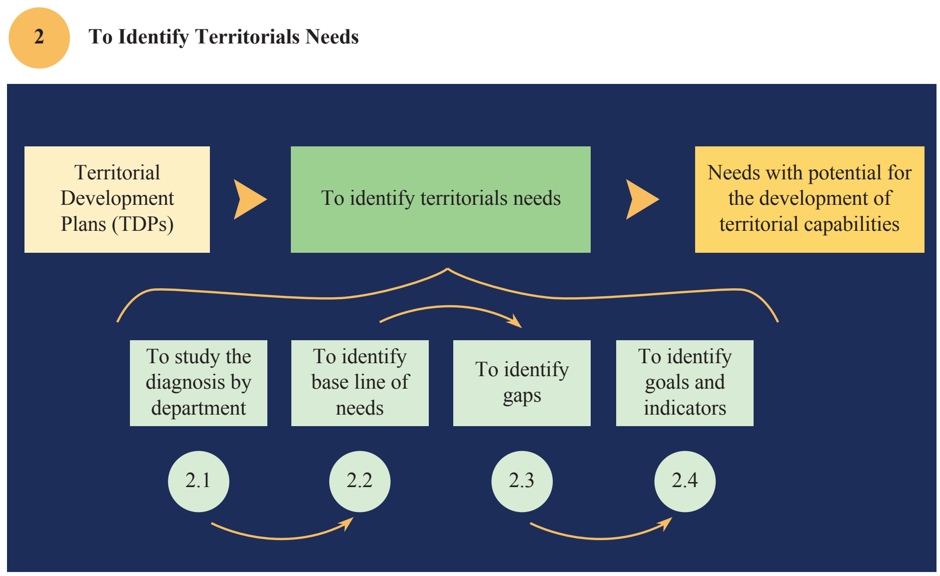
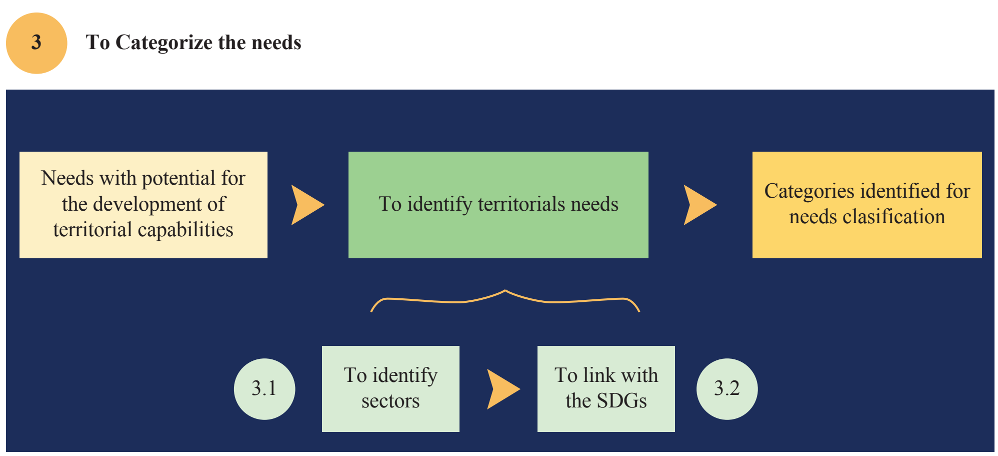


Fig. 6. Process 3 – inputs, subprocesses and outputs



The second evaluation looks at the latent potential so that the needs can be transformed into initiatives that can be developed across regions.

The evaluations will give way to the selection of needs to be transformed into project proposals for the development of regional and interregional capacities for the fluvial sector, with impact on the health, education and transport of the riverside communities (Fig. 7).

5. Prioritize projects

Based on the selection, the projects must be prioritized in compliance with risk criteria, opportunities for closing gaps and budgetary availability. This will be delivered as an output of the expected Portfolio of Projects. (Fig. 8).

On the subject of budgetary availability, the DNP provides the general public the *Royalties map*[14] tool which allows the projects and the budgets in the country financed through royalties to be consulted. It is suggested to use this application to obtain an initial approximation of the budget that is used to finance the projects within the portfolio.

14 Available at kiterritorial.co

Fig. 7. Process 4 – inputs, subprocesses and outputs

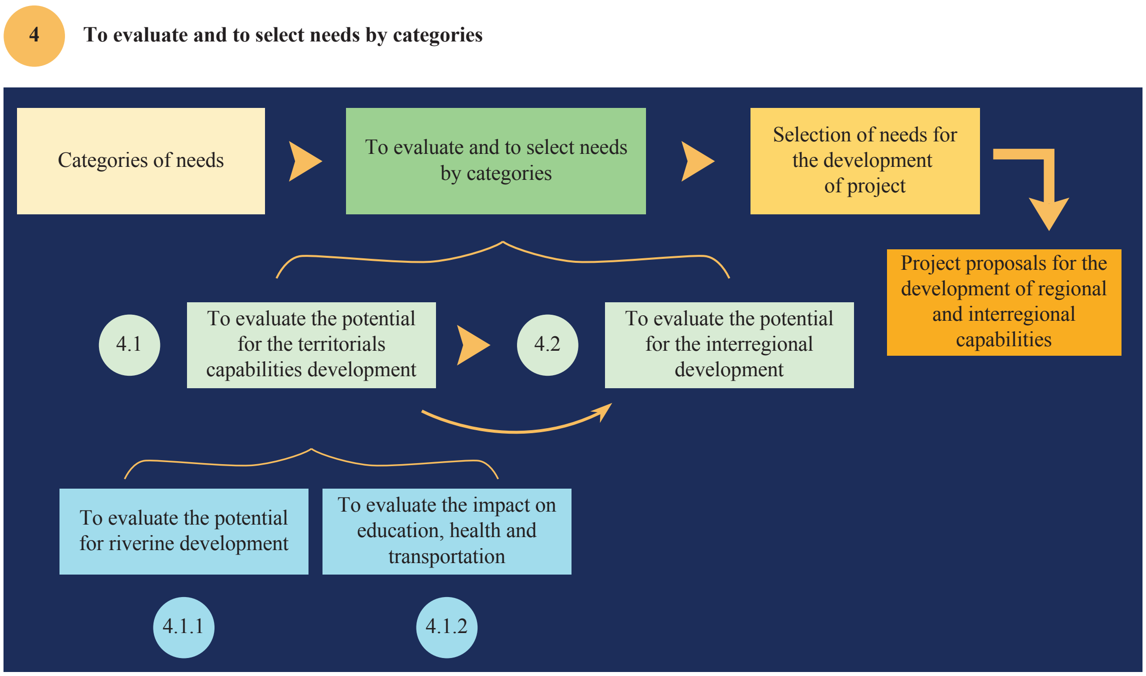
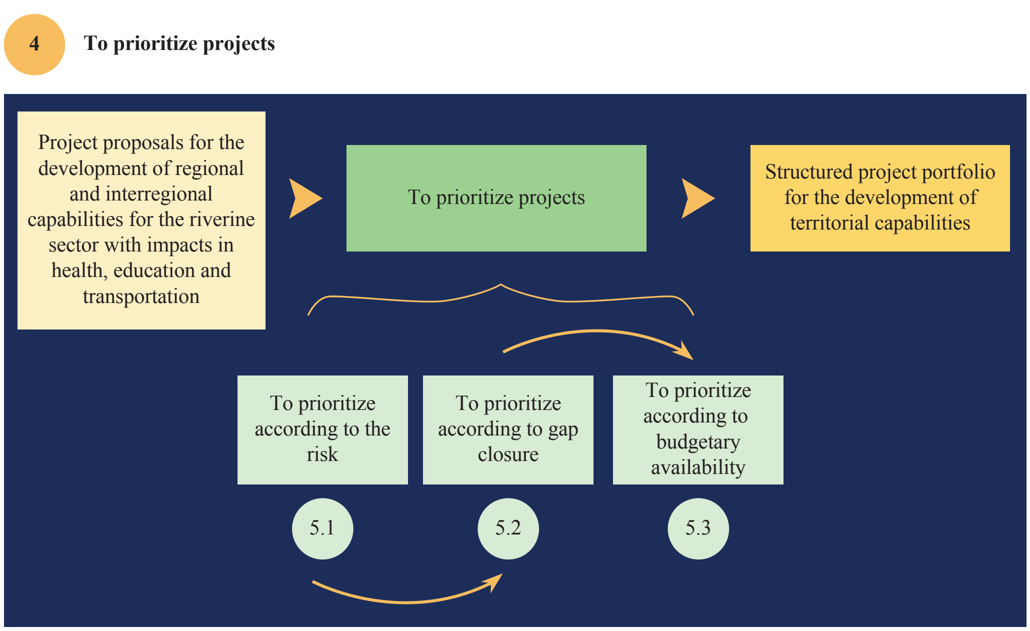


Fig. 8. Process 5 – Inputs, subprocesses and outputs



6. Submit the portfolio of projects to evaluation and approval

This process constitutes the final stage of the methodology. After having structured the portfolio of projects[15], it is necessary to disseminate them with stakeholders and potential sponsors to propose financing strategies and to submit initiatives for evaluation and approval. Depending on the evaluations made by the stakeholders, the projects are likely to require refinement or adjustment for approval. If this is the case then the process that is relevant to its improvement must be revisited.

Conclusions

Thanks to the research it was found that Colombia must make efforts to promote and consolidate its fluvial sector, with its great potential for the generation of socioeconomic impacts through the leverage of all the navigable arteries for the establishment of a transport system that supports the health and education issues of these riverside communities that are disconnected or isolated from the country's development centres.

This reality motivated the creation of a methodological proposal oriented to the identification of a portfolio of projects that is constituted by support to the development of the fluvial potential of the country.

Considering the strategic vision of the national Government in accordance with the sustainable development objectives (SDG), the portfolio of projects that emerge as a result of the application of this methodology, must ensure the connection between the needs identified by the governor´s offices of the departments and the use of rivers as a development axis to generate interregional territorial capacities.

The methodological proposal has not yet been proved, therefore, the implementation of a pilot is suggested, which can be constituted as an opportunity for improvement based on the criterion of experts in the field and those interested in developing portfolios for the development of the national capacities focused on the attention and fulfillment of the goals established by SDG.

Although this approach has been focused towards the fluvial sector, it can be adapted for its application in other sectors, considering that the conceptualization that sustains its development comes from generic structures oriented to the development of capabilities.

[15] Each project within the portfolio should be structured according to the DNP's policies for standardization, which seeks to improve the quality and efficiency of public investment (National Council for Economic and Social policy, 2015).

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Socio-economic impact of the construction of an intermodal connection in Puerto Salgar, Cundinamarca

Impacto socio-económico de la construcción de una conexión intermodal en Puerto Salgar, Cundinamarca

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Abstract

The aim of this work is to show the socio-economic impact in the Cundinamarca-Boyacá plateau produced by the construction and promotion of an alternative to relieve the freight transportation system in the region, and how it echoes in the manufacturing levels of the ship industry. For this reason, it is evaluated the option of establishing a logistics area in the town of Puerto Salgar (Cundinamarca) where may confluence an intermodal transportation system which emphasizes the Magdalena River as the main way for the country's development and Puerto Salgar as the main axis for the economic growth of the plateau. The Discrete Event Simulation (DES) methodology was used for this work, using information given by previous studies by the Ministerio de Transporte, the Dirección Nacional de Planeación and the Instituto Nacional de Vías; settting a conceptual model which determines and limit the study, and implementing a Rockwell Arena simulation.

Key words: Discrete Event Simulation, Magdalena River, Puerto Salgar, Cundinamarca-Boyacá plateau, logistics area.

Resumen

Este trabajo tiene como objetivo mostrar el impacto socio-económico en el altiplano cundiboyacense que sería producido por la construcción de una alternativa que permita aliviar el sistema de transporte de carga en la región, y su repercusión en los niveles de producción del sector astillero. Para esto se evalúa la opción de establecer un área logística en el municipio de Puerto Salgar (Cundinamarca) donde confluya un sistema intermodal de transporte que haga énfasis en el Río Magdalena como la vía principal para el desarrollo del país y Puerto Salgar como un eje del crecimiento económico del altiplano. Para esto se utilizó la metodología de Simulación de Eventos Discretos (SED), utilizando información suministrada por estudios anteriores del Ministerio de Transporte, la Dirección Nacional de Planeación, y el Instituto Nacional de Vías; estableciendo un modelo conceptual que determina y delimita el estudio propuesto, implementando una simulación en el software Rockwell Arena.

Palabras claves: Simulación de Eventos Discretos, Río Magdalena, Puerto Salgar, altiplano cundiboyacense, área logística.

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Introduction

The world economy, over the years, has experienced the effects produced by the phenomenon of globalization. Specifically, national and international markets have seen the emergence of new products, the development and evolution of some that already exist, and the failure of others, all as a result of the dynamics in the complex network of interactions present in the markets.

These effects have led to an increase in the demand for various products, at different scales, which has caused a greater flow of cargo transported all over the world.

The above has been visible in Colombia, where between 2008 and 2013 an annual average increase of 5.2% has been seen in domestic freight.

Of the entire freight moved in the country, about 18% is generated in the Cundinamarca-Boyacá plateau, where 25% of the population lives, representing 28.7% of national GDP *(Ministry of Transport, 2011)*.

A range of policies has been developed which seek to meet the needs of the region in logistical matters through various alternatives. One of them, which has been widely studied and prioritized, is the development of an intermodal connection in Puerto Salgado, Cundinamarca, where the freight transport that is generated, and attracted to the Cundinamarca-Boyacá plateau, can converge.

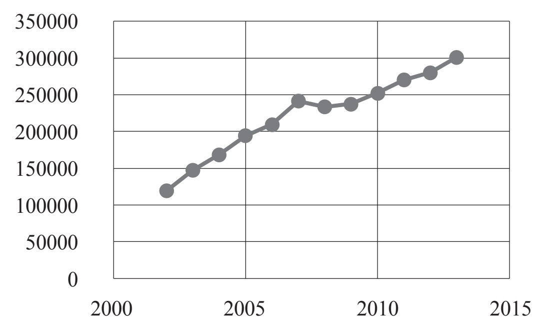
This option is the basis of this work, which seeks to study the flow of cargo that this intermodal connection would have, its socio-economic effects in the area immediately adjacent to the project and its impact on the production levels of the shipyard sector in Colombia.

Panorama of freight transport in Colombia

National level

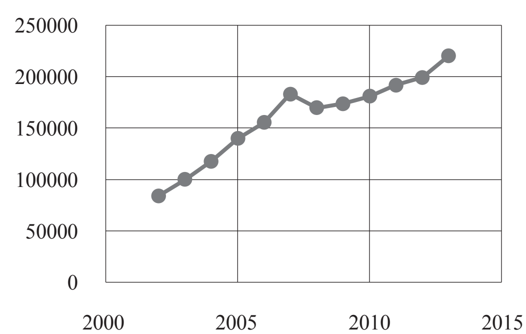
From 2002 to 2013, national freight transport has experienced linear growth attributed to the "dynamic domestic demand driven by household consumption, increased private sector investment and a stable international environment, but with a low-growth scenario" (Ministry of Transport, 2011). See Fig. 1.[1]

Fig. 1. National freight movement. (data in thousands of tons)



Cargo transport by land had the same behavior at the national level, representing on average 72% of the national total. See Fig. 2.[2]

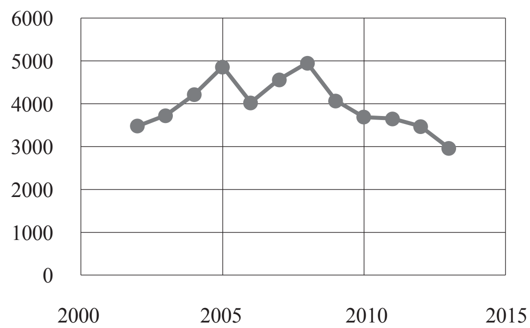
Fig. 2. National cargo transport by land (data in thousands of tons)



However, the same is not the case with fluvial transport, which displayed an irregular evolution, oscillating between 0.9% and 2.9% of the national freight transport. See Fig. 3.[3]

1 Figure based on the data obtained by the "Transport in Figures Statistical Yearbook-Statistics 2015" of the Ministry of Transport.
2 Figure based on the data obtained by the "Transport in Figures Statistical Yearbook-Statistics 2015" of the Ministry of Transport.
3 Figure based on the data obtained by the "Transport in Figures Statistical Yearbook-Statistics 2015" of the Ministry of Transport.

Fig. 3. National cargo transport by fluvial mode (data in thousands of tons)



Other modes of transport managed in the country are the railway and the air, which will not be seen in this work.

Plateau level

With regard to cargo transport in the Cundinamarca-Boyacá plateau in 2010 it had 19.2% participation in the national freight trans´port. It is expected that by 2032 this share will have increased to 22.2% of a total of 629 million tons for the year.[4]

Magdalena River Level

Cargo transport in the Magdalena River has been in a decline since the of the last century to 2010, a product of the loss of navigability of the river in different sections. However, over recent years as a result of the CONPES 3758 document that proposes a plan for the recovery and management of the Magdalena River and an interest in promoting its use as a cargo transport corridor, it has seen an increase in freight movement. See Fig. 4.[5]

Over the next few years, the goal is to gradually implement the alternative suggested by Hidroestudios S.A. for Comagdalena in 2002 for the reactivation of the navigability in the river, where the first phase in the first eight years seeks to revive the river ports of Barrancabermeja, Puerto Berrio and Puerto Salgar with a low investment and the second phase in the next twenty years with a high investment. Updating to 2017, the development of cargo transport by the River Magdalena would have this behavior. See Fig. 5.[6]

Fig. 4. Transport of cargo by the river Magdalena (data in tons)

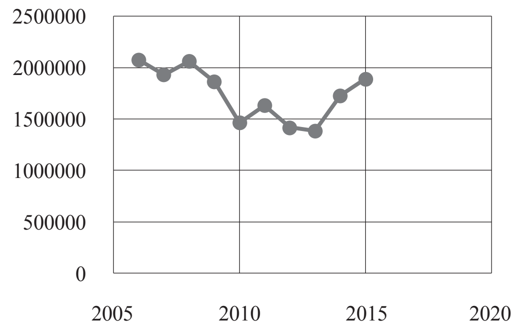
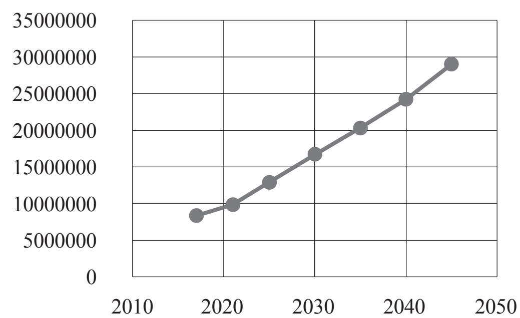


Fig. 5. Forecast for freight movement by the Magdalena River (2017-2045)



Puerto Salgar level

At present, there are no operations in the port of Puerto Salgar, although in 2014 a contract was awarded for the channeling and dredging of the river within a period of 13.5 years.[7]

At present, Puerto Salgar has a capacity as shown in Table 1.[8]

4 Source: Ministry of Transport, "Executive presentation PEIIT" (2011).

5 Figure based on the data obtained by the "Transport in Figures Statistical Yearbook -Statistics 2015" of the Ministry of Transport

6 Figure based on the data obtained from the "Demand study of Transport of the River System of Magdalena" by Cormagdalena (2002).

7 Source: http://www.eltiempo.com/colombia/otras-ciudades/puerto-salgar-la-conexion-entre-el-caribe-y-bogota/14413898

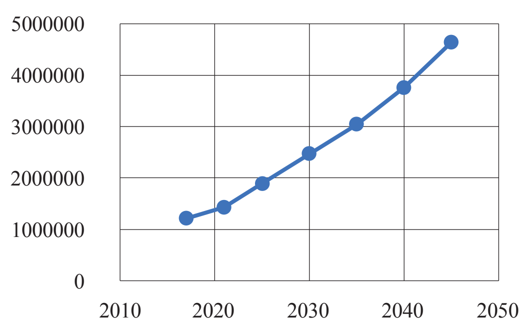
8 Data obtained from the "Demand study of Transport of the River System of Magdalena" by Cormagdalena (2002)

Table 1. Current Capacity of Puerto Salgar

Port	Puerto Salgar
Available Area M^2	
Container Yard	8971
Warehouse	2142
Loose Cargo Yard	4800
General Load Capacity (Tons/Year)	250,000
Containers (Teus/Year)	6,250
Warehouse (Tons/Year)	70,000
General Freight In Yard (Ton/Year)	75,000

As part of the alternative to reactivate the navigability of the Magdalena River, there is a forecast of the freight that Puerto Salgar would have. See Fig. 6.

Fig. 6. Forecast of freight in Puerto Salgar (2017-2045)



Defining the problem

The main objective of this work is the creation of a model that allows the transport of cargo produced in the Cundinamarca-Boyacá plateau to be simulated using an intermodal system in the municipality of Puerto Salgar.

With the model processing the most important expected results are the configuration of the fluvial fleet and the storage required to meet the demand for the transport of freight in an 8-year period for a set of sources, outputs and modes of pre-defined transport.

The facilities for the loading of trucks in the Plateau will not be subject to sizing, the same as the ground fleet required to transfer the cargo to the intermodal terminal.

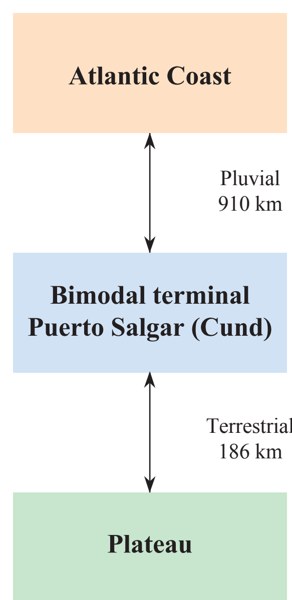
The model will be used when monitoring the service level, so that the system resources have their capacities fixed to allow the entry and exit of cargo to service per year during the defined period of time.

In this order of ideas, the main procedure to solve this sizing problem will concentrate its efforts on identifying the capacity and quantity of minimum resources per year in order to guarantee the flow of cargo.

Characterization of the system

The proposed system will have the following structure. See Fig. 7.

Fig. 7. System Structure



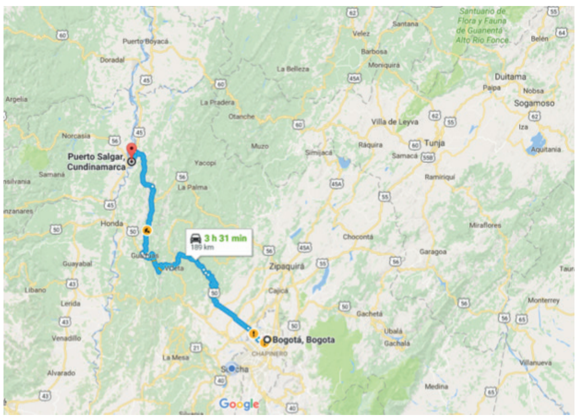
As shown in Fig. 7, the proposed system shall be composed of the following elements:

- 1 cargo flow center in the Plateau, which represents the entire cargo of the region leaving the intermodal terminal.
- 1 intermodal terminal
- 1 cargo flow center on the Atlantic coast,

which represents all the cargo entering the intermodal terminal.

For this system the freight generated in the Plateau, mainly focused in the city of Bogotá, will be transported to the municipality of Puerto Salgar. These points of interest are located in the Department of Cundinamarca, as seen in Fig. 8.

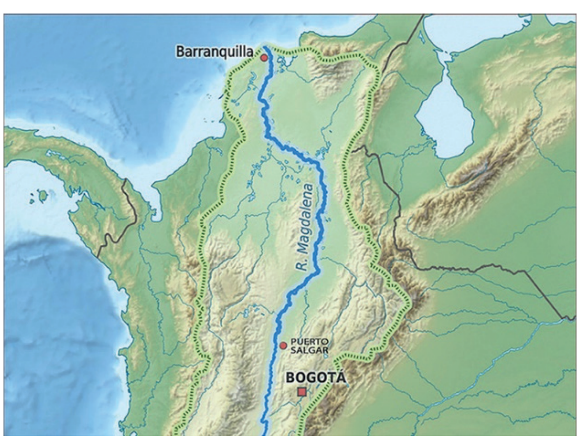
Fig. 8. Location of the points of interest



In the municipality of Puerto Salgar, the current port will be used for the construction of an intermodal terminal between the land and the fluvial mode.

The cargo will arrive at the aforementioned terminal and it will be stored in warehouses and then transferred to the river fleet that will then travel to an important port on the Atlantic coast, Barranquilla. See Fig. 9.

Fig. 9. Location of the points of interest



Considering the above description, the system will be characterized by the following subsystems:

a. Ground Transportation Subsystem
This subsystem will be composed of the road elements of the entire system, which is the only way to transport the freight generated or attracted by the Plateau towards the bimodal terminal of Puerto Salgar, where the cargo will be stored.

b. Terminal Transshipment Subsystem
The Puerto Salgar terminal will be modeled here, which will be the interface between the terrestrial and fluvial modes.

c. River Transport Subsystem
The seaport of Barranquilla will be linked to the intermodal terminal of Puerto Salgar through this system.

d. Subsystem of loading and unloading in port
Port operations will be the final subsystem of the proposed model.

Simulation model and results

Knowing the main problem and characterizing the system, a simulation model was created in Arena 14 to conduct experiments to dimension the proposed system.

It was necessary to define the main pattern scenario. This scenario is:

"Cargo transport between the port of Barranquilla and the Cundinamarca-Boyacá plateau, based on the forecast of demand expected for planning horizon of 8-years (2017 to 2025), through a type of intermodal system: land, from the main city of the Bogotá plateau to an intermodal terminal in Puerto Salgar (CUNDINAMARCA); fluvial, from the intermodal terminal of Puerto Salgar, sailing in the middle and lower areas of the river Magdalena to the port of Barranquilla (Atlántico department)."

Using the main scenario described above, a set of variables were determined within its range of values in order to test the combinations of variables looking for the best configuration that can dimensions the proposed system.

These variables were:

- Configuration of convoys.
- Storage capacity for the freight in the intermodal terminal.
- The following assumptions were considered:
- The main points of the system have warehouses to store the cargo and work 24 hours a day.
- The configuration of the convoys is one tug and two R2B2Bs, with a load capacity of 4800 tons.
- The depth of the river during the year varies between 3 ft and 6 ft.
- The system must initially allow the entry of 1,211,860 thousand tons and the exit of 1,337,893 tons.
- The system must finally allow the entry of 1,892,142 tons and an output of 2,088,924 tons.

With these definitions the system simulation was performed for a period of 15 years and 5 replications.

After performing 10 simulation scenarios the following possible configurations were given for the terminal, which are presented in Table 2.

Table 2. Possible configurations based on simulation results

River Fleet (convoys)	Storage capacity (ton/year)
10	N/A
11	N/A
12	340800
13	168000
14	100800
15	52800

From the previous results, the following fleet option is chosen as the best configuration:

- A total of 13 convoys at the end of the eight years.
- A final storage capacity of 168,000 tons/year, 23,000 ton/year above current capacity.

Analysis of results

Economic Impact

The economic impact of the construction of an intermodal platform in Puerto Salgar highlights the change in the modality of land-to-river transport due to a reduction of cost between 10% and 50% (Fedesarrollo, 2015) compared to the land transportation costs. This is due to the transport capacity of a convoy, at approximately 4,800 tons in Puerto Salgar.

Likewise, it increases the income that is perceived in the region. Taking into account that on average the flow of a TEU container would have a freight of about USD 76, and a TEU would have an average of 35 tons, and a convoy has capacity for 48,00 tons, an income is obtained from USD 2,631,467 in 2017 to USD 4.108.651 at 2025, a figure that would increase the value added in the region that was around the USD 55 million in 2013.

Social Impact

Mainly the construction of an intermodal platform will provide benefits for the generation of employment for the port population, many of them unskilled, and in addition, trainings could be offered by focusing on craft for barge management. These works will be produced by the operations of loading and unloading of trucks, storage in warehouses and patios, loading and unloading in barges, and all the administrative tasks that revolve around these activities.

Impact on the shipyard sector

At present, Puerto Salgar does not have barges for the mobilization of cargo. It is therefore necessary to buy or manufacture the 13 convoys mentioned, equivalent to 52 barges and 13 tugs. Of these, bearing in mind that law 1242 of 2008 establishes that river vessels must undergo a technical inspection every two years to keep their operating license, a potential market of 208 maintenances is projected over the 8 years of planning proposed in this work.

Conclusions

The construction of the intermodal connection in Puerto Salgar (Cundinamarca) will increase the levels of income of the region, as a result of the projected cargo flow, also the employment in the area will mainly benefit the population of the municipality by promoting unskilled jobs. Likewise, the cargo flows will increase and the logistic costs related to the use of ground transportation will be reduced.

The transport of fluvial cargo will provide relief to land transport, due to the great cargo capacity of cargo of this mode. As such it is necessary to have barges and tugs to meet thes proposed inputs and outputs in the simulation model, in order to guarantee the capacity and the flow of the cargo

Building an intermodal platform will not only have an effect on the economy of the region, it will also have an impact on the competitiveness and productivity of the commercial sector, directing river transport towards being an opportunity for the flow of the internal cargo of the country.

Through the efficient use of the means of transport, the productivity opportunities of the commercial sector provided by the construction of this platform can be leveraged.

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Logistic platform placement for harmonious development of the nation's intermodal network

Emplazamiento de plataformas logísticas para el desarrollo armónico de la red intermodal en el país

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Abstract

This article considers the problem of locating multiple installations for the intermodal transport network in Colombia, and is based on the analysis of the transport of cargo from the main generating cities to the three most important port cities in the Caribbean region of the country: Barranquilla, Cartagena and Santa Marta; integrating the modes of transport by land, road and river. According to this, land transport by road is used from the source of cargo to the possible locations of the logistic platforms, and then the Magdalena River basin is used as a unique river corridor.

The model proposed consists of determining the optimal location of a series of logistic platforms that guarantee a system of integration and cooperation in transport strategies for the country, in which aggregation and disaggregation of freight operations will be possible. In this aspect, an entire mixed programming model is performed with the objective of minimizing the total costs of transport and operation of the new intermodal network, with restrictions associated with the generation and processing of cargo, obtaining results in the cost functions related to cargo transport and leaving as evidence the potential of integrating intermodal transport for the country's competitiveness.

Key words: Logistics Platform, intermodal transport, Multi-Facility localization problem.

Resumen

Este artículo considera un problema de localización de instalaciones múltiples para la red de transporte intermodal en Colombia, para ello se analizó el transporte de carga desde las principales ciudades generadoras hasta las tres ciudades portuarias más importantes de la región caribe del país: Barranquilla, Cartagena y Santa Marta; integrando dos modos de transporte, terrestre por carretera y fluvial. De acuerdo a esto, el transporte terrestre por carretera se utiliza desde los orígenes de carga hasta las ubicaciones posibles de las plataformas logísticas, para luego usar como único corredor fluvial la cuenca del río Magdalena.

El modelo propuesto consiste en determinar la ubicación óptima de una serie de plataformas logísticas que garantizan un sistema de integración y cooperación en estrategias de transporte para el país, en las cuales serán posibles operaciones de agregación y de desagregación de carga. En este aspecto, se realiza un modelo de programación mixto entero con el objetivo de minimizar los costos totales de transporte y operación de la nueva red intermodal, con restricciones asociadas a la generación y procesamiento de carga, obteniendo resultados en las funciones de costos referentes al transporte de carga y dejando como evidencia el potencial que tiene la integración del transporte intermodal para la competitividad del país.

Palabras claves: Plataforma logística, transporte intermodal, problema de localización de instalaciones múltiples.

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Introduction

At the global level, river transport is characterized as a competitive and clean mode of transport. Costs per tonne/kilometer are low compared to other modes of transport and the carbon emissions are low *(Ministry of Transport, 2015)*. However, the movement of cargo in the waterways of the country has not increased significantly over recent years, mainly because the freight that can be transported by rivers has been essentially absorbed by the roads *(Gómez, 2012)* because only 2% of the national freight is transported by fluvial means *(ANDI, 2016)*.

Betting on an exclusive road system would mean to waste a great opportunity in building a more competitive country. An inter-modal system should be developed integrating as many modes of transport as possible. "Colombia must correct one of its biggest historical errors, abandoning river transport" *(Ospina Hernández, 2008)*.

The strengthening of inter-modal transport is a strategy that can be developed in conjunction with public and private entities with the aim of generating greater coverage in the freight and passenger transport services at reasonable costs while ensuring continuity in the service. Currently, in Colombia, the little use of intermodal transport increases logistical costs in comparison with countries that are members of the OECD *(Ministry of Transport, 2015)*.

According to the master Plan of Intermodal Transport PMTI (2015), three conditions are required to make it an effective means, first, an adequate functioning of each mode; second, an efficient connection between modes; and third, new knowledge in logistical development in the government and in the private sector. The latter defines the importance of the state in these types of initiatives, in which functions such as the promotion of infrastructure projects, economic regulation, stipulate financing mechanisms and articulate the different sectors with policies and planning that are fundamental to the effective development of an intermodal transport.

State of the art

The problem of locating facilities investigates where to locate a set of installations in a geographic or influence area with the objective of minimizing the costs and satisfying some restrictions, including the covering of some demand points in an efficient way, contemplating the flexibility and evolution of the latter in time *(Hale & Beberg, 2003)*.

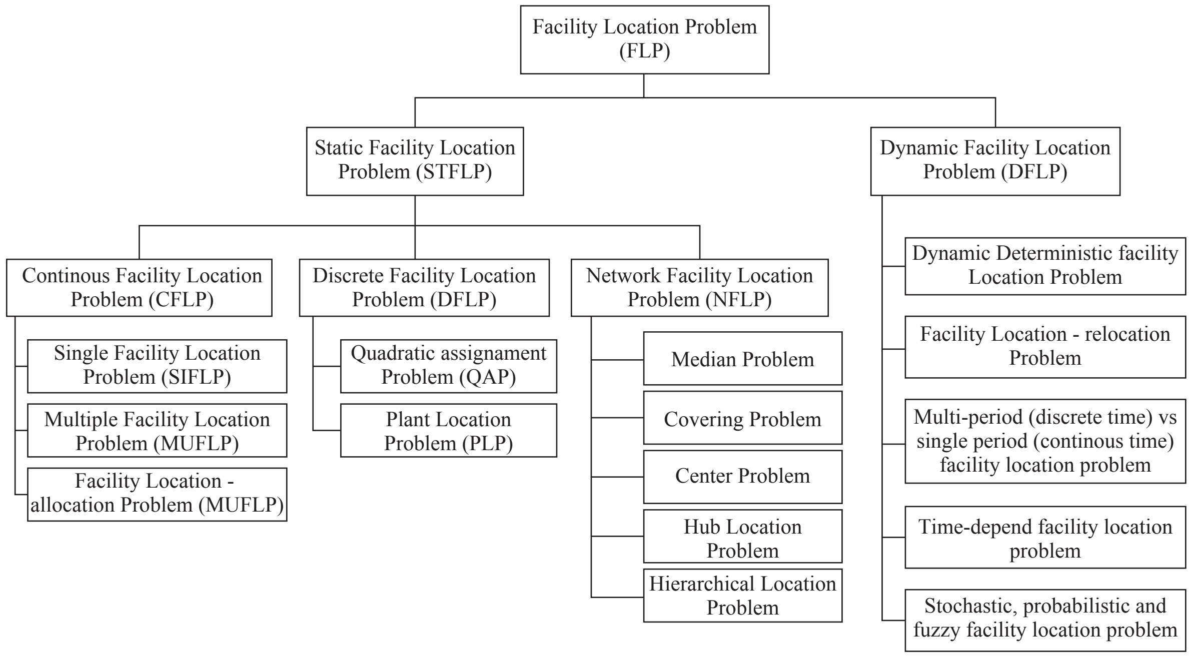
According to literature this problem has been used in a wide variety of applications in various supply chains, which include locations of material collection centers, hazardous waste locations, stations for transportation methods, service providers, recreation facilities in cities, location of bank servers, among others, which have had different characteristics in terms of their objective function, distance metrics applied, number and size of the facilities to be located, as well as other relevant characteristics in the formulation of the problem *(Hale & Beberg, 2003; Arabani & Farahani, 2011)*.

Currently the facility localization problem (FLP) is defined by two classical elements in this type of formulation: time and space, in which the concepts of geographical area of influence and travel times are incorporated from a new location to an existing one *(Arabani & Farahani, 2011)*.

Therefore, the study of this problem currently includes multiple variants, which has caused the state of the art in this regard to present various types of problems that essentially study changes in the aspects of time, area, number of facilities and other conditions *(Hale & Beberg, 2003)*, showing the following tree of variants of the original problem *(Arabani & Farahani, 2011)*: see Fig. 1.

From Fig. 1, it is possible to show some of the features that identify and differentiate typical problems associated with the Facility Location Selection problem, as indicated in table 1, in which it is possible to see what the variations of each type of sub-problem are that belong to this kind of problem that are typical of the design of productive systems.

Fig. 1. Problem tree associated with the Facility Location Problem (FLP)



Usually these types of problems generally include, in the optimization of the target location, functions related to a cost and time analysis *(Arabani & Farahani, 2011)*, where the most common are the general objective of minimizing the distance between points of the logistic network, the estimation of the minimum number of new installations and satisfaction of the demand *(Hale & Moberg, 2003)*.

As a complement, the optimization functions available in the literature on the topic show different types of objectives available in applications that are focused on minimizing costs, distance, time and risk, maximizing profits and availability of services as well as multi-criteria objectives *(Arabani & Farahani, 2011)*. Likewise it is possible to determine the use of exact techniques, heuristics, specific algorithms and general methods for the solution of this type of problems *(Arabani & Farahani, 2011)*.

As for the application of this type of modeling for problem solving, in the literary review carried out by Arabani and Farahani it is possible to find different application contexts that include chemical industries, transport, schools, medical services, electronic industries, disaster management, fire systems, military industries, production and distribution systems, the petrochemical industry, libraries, the police service and telecommunications among others *(Arabani & Farahani, 2011)*.

Finally, in the literary review it is possible to find development proposals for the topic in which the integration and combination of dynamic models of FLP are found, for which some authors initiate a process of development to obtain more favorable results in investment decision making *(Arabani & Farahani, 2011)*. Similarly, it is shown how localization problems can be seen from the supply chain, in international areas of collaboration and business integration.

Also from a criterion of the author it is possible to research FLP dynamic models in the conformation of supply networks in which the demands and the response times of the installations are probabilistic in nature, foreseeing in a better way the investment considerations. Another aspect in which the author suggests the work is in the implementation of FLP models in disaster management, from a perspective of dynamic models and how they develop a supply chain from these primary care sites *(Arabani & Farahani, 2011)*.

Methodology

As has been seen in the literature review there are different variants for the facility localization problem (FLP), grouped into two types: static and dynamic. For the object under study in this paper, the problems of static localization are those that best adjust given the characteristics and specific restrictions of the case. Within these are sub-problems that address different aspects such as time, space, number of installations, among others; which are: Discreet Location Problems (DFLP), the Localization Problem in Network installations (NFLP) and the continuous location problem (CFLP). The latter being the one that considers the problems in which each installation is located as a point in a region on a plane and the relationship between customers and facilities is a measure of distance. *(Ballou, 1968)*.

On the other hand, continuous location issues present some particular cases such as: Single-Installation location problem, Service location problem and multi-facility localization problem.

The problem of locating multiple facilities is that facilities must be located so that the Euclidean or Manhattan distance, or transportation costs with other locations are the minimum possible *(Akyuz, Oncan, & Altnel, 2009)*. In this order of ideas, this particular case allows the behavior and the interactions between the different agents that intervene in the transport of cargo in Colombia to be modelled.

Once the type of localization problem to be used has been determined, we will have as the objective the minimization of the total cost generated in the transport of a cargo unit from a point of origin to a final destination. These total costs will be disaggregated in transportation costs in two different ways and in the implementation costs of the logistics platform. In order to establish land transportation costs by road the SICE-T Transport Ministry tool is used with base prices of 2015, as for the fluvial mode, the value of the transport of one ton per kilometer is generalized from the data presented in the fluvial master plan of Colombia (2015).

For the configuration of the network three fundamental elements are defined: load-generating nodes, logistic platforms and sump nodes. As for the first element, cities were identified that generate 85% of the cargo transported to the main seaports of the Caribbean using the origin-destination matrices of the Ministry of Transport (2013). These chosen cities are Bogotá, Medellín, Cali, Villavicencio, Montería, Cúcuta, Bucaramanga and Valledupar.

Logistic platforms are intermediate network nodes that disaggregate and add load, integrating land transport modes by road and river. To select the possible locations of these platforms the main river ports on the Magdalena river are defined according to the report of the Coremar (2015) group, which are: Honda, Puerto Salgado, Puerto Berrío, Barrancabermeja, Puerto Wilches, Gamarra, El Banco, Mompós, Calamari and Barranquilla.

Finally, the sinking nodes or final destinations arise because of their location near the mouth of the Magdalena River, a river corridor involved in the intermodal network that is defined in this study. These nodes are: Cartagena, Barranquilla and Santa Marta.

Model and assumptions

As mentioned above the network under study has three main elements, Origins (i), Platform (j) and Destination (k).

Assumptions:

- Cargo flows only have one direction, from the cargo generating cities to the coastal cities destination k.
- Land transport by road is carried out by means of a single type of vehicle configuration (C3).
- The cargo is of the general type and non-differential.
- No load-and-unload operations are performed between nodes.

- Platforms have limited capacity.
- For all cargo entering the platforms j is equal to the cargo that leaves.

The parameters and variables used in the model are as follows:

Sets:

i Set of Origins ($i = 1,2,3,\ldots,I$)
j Set of Platforms ($j = 1,2,3,\ldots,J$)
k Set of Destinations ($k = 1,2,3,\ldots,K$)

Parameters:

$CTR1_{i,j}$: Cost of transport per ton of cargo between the cities of origin type i and the possible location of the logistic platform j [*$/ton*]
$CTR2_{j,k}$: Cost of transport per ton of cargo between the logistic platforms type j and destination ports type k [*$/ton*]
Ch_j: Operating cost per year in the logistics platform type j [*$/año*]
$Capc_j$: Storage and handling capacity in the logistics platform type j [*Ton/year*]
$CarGen_j$: Amount of cargo generated in the city of origin type i [*Ton/year*]
Pue_k: Amount of load to handle in the destination port type k [*Ton/year*]
N: Maximum number of logistic platforms to install [Facilities]

Decision Variables:

CT: Total cost of transport and operation of the logistic system
$X_{i,j}$: Amount of cargo to be transported between the city of origin type i and the Logistics Platform Type j [*ton/year*]
$Y_{i,j}$: Amount of cargo to be transported between the logistic platform Type j and destination Type city k [*ton/year*]
Z_j: 1: If the platform j comes into operation; 0: in another case

With the detailed notation above it is possible to formulate a whole mixed programming model (MIP) as follows:

$$Min \sum_{i\in I}\sum_{j\in J} CTR1_{i,j} \times X_{i,j} + \sum_{j\in J}\sum_{k\in K} CTR2_{j,k} \times Y_{j,k} + \sum_{j\in J} Ch_j \times Z_j \qquad (1)$$

$$\sum_{i\in I} X_{i,j} \le Capc_j \times Z_j; \quad \forall j \qquad (2)$$

$$\sum_{j\in J} X_{i,j} \ge CarGen_i; \quad \forall i \qquad (3)$$

$$\sum_{i\in I} X_{i,j} - \sum_{k\in K} Y_{j,k} = 0 \qquad (4)$$

$$\sum_{j\in J} Y_{j,k} \ge Pue_k; \quad \forall k \qquad (5)$$

$$\sum_{j\in J} Z_j \le N \qquad (6)$$

$$Z_j \in \{0,1\}; \quad (j \in J) \qquad (7)$$

$$X_{i,j} \ge 0; \quad (i \in I;\ j \in J) \qquad (8)$$

$$Y_{j,k} \ge 0; \quad (j \in J;\ k \in K) \qquad (9)$$

Results Analysis

This section presents the computational results of the mathematical model developed for the problem being studies, in two different scenarios. GAMS 23.9.5 software is used to model said Issue and the Excel financial tool for submitting tables.

Initially the behavior of the system is analyzed by restricting the platform number to implement to four, in order to determine if each of these can withstand the volume generated at least in two cities. To make this possible the model is allowed to adjust the capacity of the platforms according to the requirements of cargo flows from the generating nodes.

By implementing four platforms, the river ports of Honda, Puerto Berrio, Gamarra and Calamar are activated, receiving 4,509,037, 2,041,024, 2,374,354 and 913,809 tonnes respectively, See Table 1. The cargo that arrives to Honda comes from the cities of Cali (29%), Bogotá (60%) and Villavicencio (11%), being the platform that welcomes the highest volume equivalent to 46% of total transported cargo. The provenance of the cargo that arrives to Puerto Berrio is exclusively from Medellín which represents 21% of the total transported. For its part Gamarra manages 24% of the total transported distributed from Cúcuta (48%) and Bucaramanga (52%). Finally, Calamar moves the remaining load which comes from Montería (54%) and Valledupar (46%). The costs recorded by mobilizing cargo from the generator nodes to the platforms are COP 481,852,000,000.

From the above it is evident that each platform functions as a receiving point of freight for the main regions of the country, distributed as follows: Honda mainly receives freight from the south of the country; Puerto Berrio from the west; Gamarra from the north east zone; and Calamar from the Caribbean region. In this way It takes full advantage of the extent of the river in the national territory.

Continuing with flows from the J-platforms to the K-destinations the model gives the load distribution shown in Table 2. This distribution satisfies the demand requirements of each of the three major port cities in the Colombian Caribbean. Barraquilla accounts for 48% of the total of the mobilized cargo, corresponding to 4,696,840 tonnes during the year, coming from the river ports of Honda, Puerto Berrio and Gamarra. Cartagena on the other hand, receives 42% divided between Honda and Calamar. Finally, Santa Marta moves the remaining 10% of the cargo from Gamarra.

Table 1. Cargo flows between origin cities origin and the logistic platforms of the first scenario

	Hda	Pbr	Gmr	Cal
Bog	2.715.291			
Med		2.041.024		
Clo	1.302.248			
Vvc	491.498			
Mtr				488.468
Cuc			1.146.532	
Bga			1.227.822	
Vup				425.341
Cap. Req	4.509.037	2.041.024	2.374.354	913.809

Table 2. Cargo flows between logistics platforms and destination cities target of the first scenario

	Hda	Pbr	Gmr
Hda	1.303.612	3.205.425	
Pbr	2.041.024		
Gmr	1.352.204		1.022.150
Cal		913.809	

The transport costs generated by this route are calculated in COP 422,354,000,000 per year, the total cost of this operation by integrating the land and river modes ascends to COP 904,206,000,000.

On the other hand, in a second scenario where the model has autonomy to choose the optimal solution, the restriction corresponds to the platform number to implement and a theoretical capacity is established for each of them in order to prevent them from influencing the decision, taking as a criterion that these can cover at least twice the supply of the city that the higher load volume generates. This scenario shows an optimal solution in which the platforms of the previous model are maintained and includes two more as are Barrancabermeja and the same port of Barranquilla see Table 3.

Table 3. Cargo flows between cities of origin and logistic platforms of the second scenario

	Hda	Pbr	Gmr	Cal	Baq
Bog	2.715.291				
Med		2.041.024			
Clo	1.302.248				
Vvc	491.498				
Mtr				488.468	
Cuc			1.146.532		
Bga					
Vup					425.341
Cap. Req	4.509.037	2.041.024	1.146.532	488.468	425.341

Table 4. Cargo flows between logistics platforms and second scenario destination cities

	Baq	Ctg	Smr
Hda	878.271	3.360.766	
Pbr	2.041.024		
Eja	1.227.822		
Gmr	124.382		1.022.150
Cal		488.468	
Baq	425.341		

The total costs corresponding to the last segment of the network resulting from the operation of the fluvial mode are calculated in COP 434,470,000,000, an increase of 2% compared to the previous value under the same modality. Although it can be observed that river costs increased by the opening of two new platforms, this network configuration presents lower total costs. Fig. 2 graphically shows the solution found, signals the origin cities and direction of the cargo flows to each platform.

From the information collected on the previously mentioned land transportation costs and the load volumes mobilized for one year, the total annual cost of this operation has been determined using only this mode of transport, with the objective of contrasting the results that the proposed model throws.

For a year of transport only by road from the main cities generating cargo to the port cities of the Caribbean the costs rise to COP 1.73 Billion. It is clear that the implementation of the logistic platforms located in the geographical points suggested by the model represents a reduction In the costs of the order of 50% in relation to the current operation.

In Figs. 3, 4 and 5, the cost per route is detailed for origin-destination cntrasting the current operation and intermodal network settings established in the second scenario proposed.

Conclusions

According to the results obtained in the two modeling scenarios, it is evident that the implementation of logistic platforms at critical points significantly reduces total transport costs. In addition, the effective integration of at least two transportation modes through the logistic platforms allow the development of the intermodal network in the country.

It necessary to recover the navigability of the Magdalena river to make the implementation of an intermodal network of this type possible, in which the modes of river transport and land by road of the country are integrated. By allowing cargo transport in large volumes by this the main river corridor of the country, a resource would be exploited that is wasted right now, which as the figures indicate currently transport just 2% of the total national freight.

Fig. 2. Proposed Intermodal network

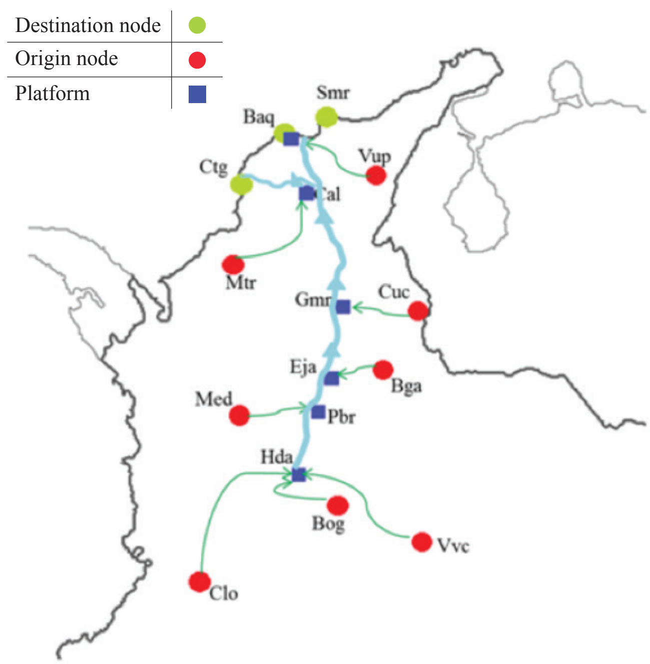


Fig. 3. Cost of transportation to the city of Barranquilla in Colombian pesos

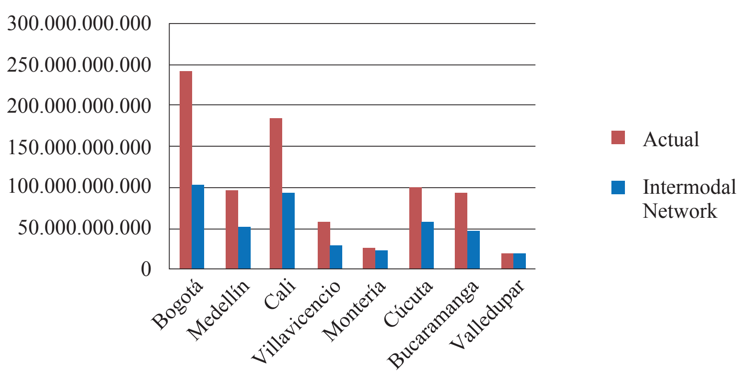


Fig. 4. Cost of transportation to the city of Cartagena In Colombian pesos

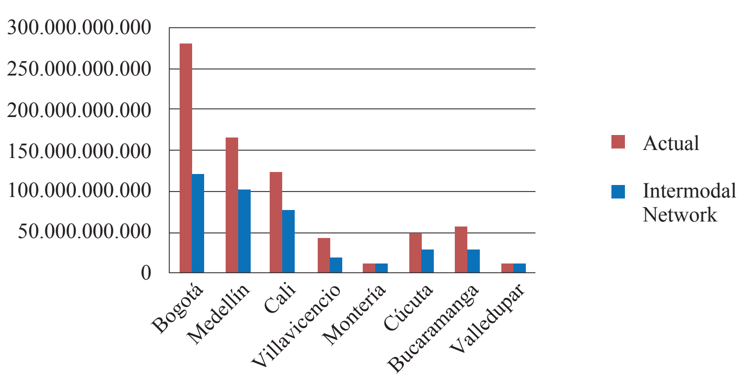
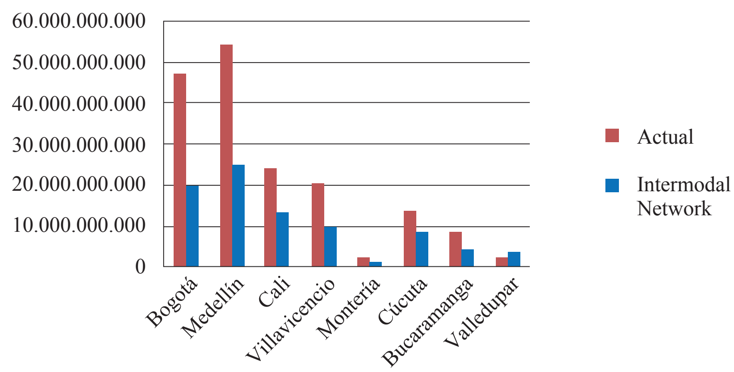


Fig. 5. Cost of transportation to the city of Santa Marta In Colombian pesos



This work gives rise to continue researching and designing new configurations of the intermodal network that the country needs. Although here we propose specific places for the implementation of logistic platforms, it is necessary to continue validating each one of these models with new economic, social and even cultural variables, to measure more precisely the impacts that can be generate on the areas of influence.

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Typology

The *Ship Science and Technology* Journal accepts to publish articles classified within the following typology (COLCIENCIAS 2006):

- *Scientific and technological research articles*. Documents presenting detailed original results of finished research projects. Generally, the structure used contains four important parts: introduction, methodology, results, and conclusions.
- *Reflection Articles*. Documents presenting results of finished research as of an analytical, interpretative, or critical perspective of the author on a specific theme, resorting to original sources.
- *Revision Articles*. Documents resulting from finished research in the field of science or technology in which published or unpublished results are analyzed, systemized, and integrated to present advances and development trends. These are characterized by presenting an attentive bibliographic revision of at least 50 references.

Format

All articles must be sent to the editor of The *Ship Science and Technology* Journal accompanied by a letter from the authors requesting their publication. Every article must be written in *Microsoft Word* in single space and sent in magnetic form.
Articles must not exceed 10,000 words (9 pages).
File must contain all text and any tabulation and mathematical equations.
All mathematical equations must be written in *Microsoft Word Equation Editor*. This file must contain graphs and figures; additionally, they must be sent in a modifiable format file (soft copy). Also, abbreviations and acronyms have to be defined the first time they appear in the text.

Content

All articles must contain the following elements that must appear in the same order as follows:

Title
It must be concise (no more than 25 words) with appropriate words so as to give readers an idea of the contents of the article. It must be sent in English and Spanish language.

Author and Affiliations
The author's name must be written as follows: last name, initial of first name . Affiliations of author must be specified in the following way and order:

- Business or institution (including department or division to which he/she belongs).
- Street mailing address.
- City (Province/State/Department).
- Country.

Abstract

A short essay of no more than one hundred fifty (150) words, specifying content of the work, scope, and results. It must be written in such a way so as to contain key ideas of the document. It must be sent in English and Spanish language.

Key Words

Identify words and/or phrases (at least three) that recover relevant ideas in an index. They must be sent in English and Spanish language.

Introduction

The text must be explanatory, clear, simple, precise, and original in presenting ideas. Likewise, it must be organized in a logical sequence of parts or sections, with clear subtitles to guide readers. The first part of the document is the introduction. Its objective is to present the theme, objectives, and justification of why it was selected. It must contain sources consulted and methodology used, as well as a short explanation of the status of the research, if it were the case, and form in which the rest of article is structured.

Body Article

It is made up of the theoretical framework supporting the study, statement of the theme, status of its analysis, results obtained, and conclusions.

Equations, Tables, Charts ang Graphs

All of these elements must be numbered in order of appearance according to their type and must have their corresponding legends, along with the source of the data.

Equations must be numbered on the right hand side of the column containing it, in the same line and in parenthesis. The body of the text must refer to it as "(Equation x)". When the reference starts a sentence it must be made as follows: "Equation x". Equations must be written so that capital letters can be clearly differentiated from lower case letters. Avoid confusions between the letter "l" and the number one or between zero and the lower case letter "o". All sub-indexes, super-indexes, Greek letters, and other symbols must be clearly indicated. All expressions and mathematical analyses must explain all symbols (and unit in which they are measured) that have not been previously defined in the nomenclature. If the work is extremely mathematical by nature, it would be advisable to develop equations and formulas in appendixes instead of including them in the body of the text.

Figure/Fig. (lineal drawings, tables, pictures, figures, etc.) must be numbered according to the order of appearance and should include the number of the graph in parenthesis and a brief description. As with equations, in the body of the text, reference as "(Fig. X)", and when reference to a graph is the beginning of a sentence it must be made as follows: "Fig. x".

Charts, graphs, and illustrations must be sent in modifiable vector file format (*Microsoft Excel, Microsoft Power Period*, and/or *Microsoft Vision*).

Pictures must be sent in TIF or JPG format files, separate from the main document in a resolution higher than 1000 dpi.

Foot Notes

We recommend their use as required to identify additional information. They must be numbered in order of appearance along the text.

Acknowledgment

Acknowledgments may be made to persons or institutions considered to have made important contributions and not mentioned in any other part of the article.

Bibliographic References

The bibliographic references must be included at the end of the article in alphabetical order and shall be identified along the document. To cite references, the Journal uses ISO 690 standards, which specify the mandatory elements to cite references (monographs, serials, chapters, articles, and patents), and ISO 690-2, related to the citation of electronic documents. We also use IEEE standard for the bibliographic references.

ISO 690

Quotations
They must be made in two ways: at the end of the text, in which case the last name of author followed by a comma and year of publication in the following manner:

"Methods exist today by which carbon fibers and prepregs can be recycled, and the resulting recyclate retains up to 90% of the fibers' mechanical properties" (*Davidson, 2006*).

The other way is:

Davidson (2006) manifests that "Methods exist today by which carbon fibers and prepregs can be recycled, and the resulting recyclate retains up to 90% of the fibers' mechanical properties".

List of References
Bibliographic references of original sources for cited material must be cited at the end of the article in alphabetical order and according to the following parameters:

In the event of more than one author, separate by commas and the last one by an "and". If there are more than three authors write the last name and initials of the first author and then the abbreviation "*et al.,*".

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INSTITUTION NAME. *Title of publication*. Subordinate responsibility (optional). Edition. Publication (place, publisher). Year. Extent. Series. Notes. Standard Number.

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AMERICAN SOCIETY FOR METALS. *Metals Handbook: Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals*. 9th edition. Asm Intl. December 1980. ISBN: 0871700093.

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UNITED STATED OF AMERICAN. EPA - U.S. Environmental Protection Agency. Profile of the Shipbuilding and Repair Industry. Washington D.C. 1997. P. 135.

Journal Article

Basic form:
Last name, N.I. Title of article, *Name of publication*. Edition. Year, issue designation, Pagination of the part.

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Example:
CARL ZEISS JENA, VEB. *Anordnung zur lichtelektrischen Erfassung der Mitte eines Lichtfeldes. Et-finder*: W. FEIST, C. WAHNERT, E. FEISTAUER. Int. Cl.3 : GO2 B 27/14. Schweiz Patentschrift, 608 626. 1979-01-15.

Presentation at conferences or academic or scientific event

Basic form:
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Example:
VALENCIA, R., et al. Simulation of the thrust forces of a ROV En: COTECMAR. P*rimer Congreso Internacional de Diseño e Ingeniería Naval CIDIN 09*. Colombia, Cartagena: COTECMAR, 2009.

Internet

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[1] LAST NAME, N.I. *Title of work*, [on-line]. Available at: http://www.direccion_completa.com, recovered: day of month of year.

Example:
[1] COLOMBIA. ARMADA NACIONAL. COTECMAR gana premio nacional científico, [web on-line]. Available at: http://www.armada.mil.co/?idcategoria=545965, recovered: 5 January of 2010.

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IEEE Publications uses Webster's College Dictionary, 4th Edition. For guidance on grammar and usage not included in this manual, please consult The Chicago Manual of Style, published by the University of Chicago Press.

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Basic form:
[1] J. K. Author, "Title of chapter in the book," in *Title of His Published Book*, *x*th ed. City of Publisher, Country if not USA: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx*.

Example:
[1] B. Klaus and P. Horn, *Robot Vision*. Cambridge, MA: MIT Press, 1986.

Handbooks

Basic form:
[1] *Name of Manual/Handbook*, *x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, year, pp. *xx-xx*.

Example:
[1] *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.

Reports
The general form for citing technical reports is to place the name and location of the company or institution after the author and title and to give the report number and date at the end of the reference.

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[1] J. K. Author, "Title of report," Abbrev. Name of Co., City of Co., Abbrev. State, Rep. *xxx*, year.

Example:
[1] E. E. Reber *et al.*, "Oxygen absorption in the earth's atmosphere," Aerospace Corp., Los Angeles, CA, Tech. Rep. Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.

Conference Technical Articles
The general form for citing technical articles published in conference proceedings is to list the author/s and title of the paper, followed by the name (and location, if given) of the conference

publication in italics using these standard abbreviations. Write out all the remaining words, but omit most articles and prepositions like "of the" and "on." That is, *Proceedings of the 1996 Robotics and Automation Conference* becomes *Proc. 1996 Robotics and Automation Conf.*

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[1] J. K. Author, "Title of paper," in *Unabbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), year, pp. xxx-xxx.

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The following sources are unique in that they are electronic only sources.

FTP

Basic form:
[1] J. K. Author. (year). Title (edition) [Type of medium]. Available FTP: Directory: File:

Example:
[1] R. J. Vidmar. (1994). *On the use of atmospheric plasmas as electromagnetic reflector*s [Online]. Available FTP: atmnext.usc.edu Directory: pub/etext/1994 File: atmosplasma.txt.

WWW

Basic form:
[1] J. K. Author. (year, month day). Title (edition) [Type of medium]. Available: http://www.(URL)

Example:
[1] J. Jones. (1991, May 10). Networks (2nd ed.) [Online]. Available: http://www.atm.com

E-Mail

Basic form:
[1] J. K. Author. (year, month day). Title (edition) [Type of medium]. Available e-mail: Message:

Example:
[1] S. H. Gold. (1995, Oct. 10). *Inter-Network Talk* [Online]. Available e-mail: COMSERVE@RPIECS Message: Get NETWORK TALK

E-Mail

Basic form:
[1] J. K. Author. (year, month day). Title (edition) [Type of medium]. Available Telnet: Directory: File:

Example:
[1] V. Meligna. (1993, June 11). *Periodic table of elements* [Online]. Available Telnet: Library.CMU.edu Directory: Libraries/Reference Works File: Periodic Table of Elements

Patents

Basic form:
[1] J. K. Author, "Title of patent," U.S. Patent x xxx xxx, Abbrev. Month, day, year.

Example:
[1] J. P. Wilkinson, "Nonlinear resonant circuit devices," U.S. Patent 3 624 125, July 16, 1990.

Standards

Basic form:
[1] Title of Standard, Standard number, date.

Example:
[1] IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.

Theses (M.S.) and Dissertations (Ph.D.)

Basic form:
[1] J. K. Author, "Title of thesis," M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

Example:
[1] J. O. Williams, "Narrow-band analyzer," Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.

Unpublished
These are the two most common types of unpublished references.

Basic form:
[1] J. K. Author, private communication, Abbrev. Month, year.
[2] J. K. Author, "Title of paper," unpublished.

Examples:
[1] A. Harrison, private communication, May 1995.
[2] B. Smith, "An approach to graphs of linear forms," unpublished.

Periodicals
NOTE: When referencing IEEE Transactions, the issue number should be deleted and month carried.

Basic form:
[1] J. K. Author, "Name of paper," *Abbrev. Title of Periodical*, vol. *x*, no. x, pp. *xxx-xxx*, Abbrev. Month, year.

Examples:
[1] R. E. Kalman, "New results in linear filtering and prediction theory," J. Basic Eng., ser. D, vol. 83, pp. 95-108, Mar. 1961.

References
NOTE: Use *et al*. when three or more names are given.

References in Text:
References need not be cited in the text. When they are, they appear on the line, in square brackets, inside the punctuation. Grammatically, they may be treated as if they were footnote numbers, e.g.,

as shown by Brown [4], [5]; as mentioned earlier [2], [4]–[7], [9]; Smith [4] and Brown and Jones [5]; Wood et al. [7]

or as nouns:

as demonstrated in [3]; according to [4] and [6]–[9].

References Within a Reference:
Check the reference list for ibid. or op. cit. These refer to a previous reference and should be eliminated from the reference section. In text, repeat the earlier reference number and renumber the reference section accordingly. If the ibid. gives a new page number, or other information, use the following forms:

[3, Th. 1]; [3, Lemma 2]; [3, pp. 5-10]; [3, eq. (2)]; [3, Fig. 1]; [3, Appendix I]; [3, Sec. 4.5]; [3, Ch. 2, pp. 5-10]; [3, Algorithm 5].

NOTE: Editing of references may entail careful renumbering of references, as well as the citations in text.

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