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CNR–Fincantieri Joint Projects: A Successful Example of Collaboration between Research and Industry Based on the Open Innovation Approach

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Abstract: This paper contributes to the open innovation literature by presenting a successful application of the open innovation approach in the maritime sector between Fincantieri (FC), one of the world's largest shipbuilding groups, and the National Research Council of Italy (CNR, Consiglio Nazionale delle Ricerche), the largest research entity in Italy. By using external sources of scientific innovation, specifically 10 different groups of researchers from CNR research institutes and three universities, and by integrating these groups with a team of expert Fincantieri's designers, the company obtained significant advances in terms of technological content and competitiveness. This collaboration is an evident example of successful implementation of the open innovation paradigm, where a big company (Fincantieri) uses external sources of innovation (the CNR researchers) to advance its technology by carrying out six different projects simultaneously. The paper presents the adopted open innovation model, the governance approach specifically implemented by the company and the major scientific contents and outcomes of the constellation of the six connected projects.

Keywords: Open innovation; research and technological transfer; maritime transport; digital technologies; management

1. Introduction

The issue of open innovation is today a strongly felt problem, as documented by the numerous studies present in the literature. This paradigm, initially started as a research interest of a few people in the field of the technology and innovation management, is currently often also cited in strategy, general management, and organization behavior journals [1]. The introduction of the open innovation paradigm definitively ended the era of closed innovation, and now the innovation process is studied in management literature according to different perspectives, such as the direction of openness, the types of partners, the kind of governance of the innovation network, and so on [2].

The open innovation approach is the opposite of the “closed innovation” approach, which assumed that the best route to innovation was to have control over the entire process (hiring the best employees, keeping data internally, and so on). As a matter of fact, companies can hardly approach innovation issues only relying entirely on their own assets; moreover, they can hardly find the internal skills necessary to tackle complex multidisciplinary problems. Very often, they acquire know-how or specific inventions, also in the form of patents, from external firms. From the perspective of the open innovation paradigm, companies find a path to overcome internal limits by taking advantage of external innovation drivers, such as academic institutions, competitor companies, customers, and so on. This approach entails also a change in the use and management of the intellectual property. The adoption of the open innovation approach makes permeable the boundaries of companies, and this enables the synergic combination of the resources coming from both the companies and the external collaborators.

In general, large organizations have at their disposal key resources, in terms of skills and finances, that small- and medium-sized enterprises (SMEs) do not have. Thus, SMEs with resource constraints, on one hand, can overcome their limits through collaboration and networking with other organizations; on the other hand, the application of open innovation is critical for them just due to their typical limited resources to manage the innovation process [3–5].

However, the cooperation between firms can generate critical technological bottlenecks due to the fact that “complementary” firms can have little incentive to invest in developing novel technological solutions that primarily benefit the hub firm [6]. A solution to this paradigm is discussed in Reference [7], where outbound open innovation is proposed to accelerate technological progress in inter-firm collaborations, thus removing technological bottlenecks in their business ecosystem. This model highlights that two factors are critical for the successful deployment of the new technologies, i.e., their potential to extend the portfolios of the service providers, and the control over the intellectual property.

Initially, open innovation research provided evidence of various positive influences for large companies in the United States of America (USA), such as IBM, Lucent, and Intel, DSM Holding company, or Procter&Gamble (P&G) company. Moreover, the public administration, during the Obama administration, felt the need to integrate open innovation processes to solve some problems of public management [8]. Another example of the open innovation approach in big companies was shown in Reference [1], which described the alliance between IBM and ETH Zurich in Switzerland and highlighted the benefits for both parties; however, it did not give evidence of the collaboration model implemented. Another interesting study [9] was based on interviews conducted with reference figures for open innovation within two Swedish big companies.

The present paper moves forward along the line of the open innovation approach among big organizations. The paper does not intend to investigate new open innovation models, to compare different open innovation models, or to fix milestones in the open innovation theory, which is outside of the authors’ expertise. The main aim of the present work is to present an example of implementation and realization of a successful open innovation model applied by one of the largest ship builders in the world, i.e., Fincantieri (FC), and the largest research institution in Italy, i.e., the National Research Council (CNR). Fincantieri resorted to the external knowledge of CNR in order to provide fuel to their business models and to convert research and development (R&D) into commercial value. The open innovation approach here adopted can be categorized as a so-called “coupled innovation process”,

where the firm (FC) works together with the external sources of innovation (the CNR researchers) to develop new solutions and new knowledge. The model was simultaneously applied to six different projects (all dealing with six different aspects of the ship and its services and systems) that were carried out in parallel by CNR and Fincantieri in the same time period of two years. The main actors are the human resources involved in these projects, who are responsible for creating collaborative knowledge processes. In an open innovation paradigm, it is essential for R&D personnel to possess a background of data and knowledge that permits them to speak and interact with researchers and managers of other industrial sectors. The practical implications of this approach are highlighted in Section 9, in terms of the added value for both Fincantieri and CNR.

The paper is organized in 10 sections. After the Introduction in Sections 1–3 describe the main actors in this experiment model, i.e., FC and CNR, respectively. Section 4 details the open innovation paradigm adopted. Section 5 presents a brief description of the activity carried out in the six projects that have represented the test bed of this experiment. Section 6 describes the main barriers related to this paradigm and how they can be overcome. Sections 7 and 8 describe in detail the structure of the management model, the procedures followed throughout the execution of the projects, and the results obtained by following the aforementioned procedures. Section 9 highlights what each partner has gained at the end of the experiment and briefly presents the business model of Fincantieri. Conclusions in Section 10 end the paper, giving an indication of the new project where Fincantieri is now applying the successful model here presented.

2. Fincantieri and Innovation in Fincantieri

Fincantieri is one of the world's biggest shipbuilding business networks and a favorite for diversification and innovation of its components. Fincantieri is a leader in cruise liner design and construction and a reference player throughout high-tech industry sectors, from naval to offshore vessels, from high-complexity special vessels and ferries to mega yachts, as well as in ship repairs and conversions, production of systems, and mechanical and electrical component equipment and after-sales services.

Fincantieri has a complex range of products that make it confident in its innovation processes, which are based both on internal skills and on the capability to establish synergy with external players; this allows creating a continuous virtuous exchange of competence and knowledge from different sectors and geographical areas.

Fincantieri is one of the largest nationally and internationally system integrators. This role requires that Fincantieri is able to establish long-lasting and mutually trusting relationships with all its suppliers in order to pursue a shared growth path based on the constant introduction of the latest technological discoveries proposed by its stakeholders in order to maintain high standards of quality, cost, and risk reduction. This demonstrates that the group is daily engaged in the application of the typical growth models of open innovation and knows its dynamics, strengths, and weaknesses in detail.

Fincantieri has a research and development area divided into three reference sections:

- The first section, development of technologies and innovation applied to the order, is responsible for all those activities aimed at developing technological solutions, innovative systems, and materials from the first planning stages of the construction process of a new ship to meet the requests and the needs expressed by shipowners.
- The second one, off-the-shelf innovation section, deals with identifying and finding technologically advanced solutions to respond to various more general problems that are not directly posed by shipowners, but which serve to improve production standards such as energy efficiency, reduction of operating costs, maximization of the payload, etc.
- Finally, the long-term innovation section deals with the study of new technologies and products that can allow Fincantieri to approach new sectors.

The six projects carried out in collaboration with the CNR and the universities, described in this work, saw the involvement of the last two sections, and they are addressed to meet the future challenges that FC will be presented with.

3. The National Research Council of Italy (CNR) and Its Approach to Industry-Driven Innovation

The National Research Council (CNR) is the largest public research institution in Italy, the only one overseen by the University and Research Ministry (MIUR) performing multidisciplinary activities. Founded in November 1923, CNR's mission is to perform research in its own institutes, to promote innovation and competitiveness of the national industrial system, to promote the internationalization of the national research system, to provide technologies and solutions to emerging public and private needs, to advise the government and other public bodies, and to contribute to the qualification of human resources. The main resource of CNR is its 360-degree knowledge, which means people, with their skills, commitment, and ideas. About 8400 employees work at CNR, with 6000 being researchers and technologists. CNR acknowledges the importance of any action aimed at promoting European leadership enabling industrial technologies and, consequently, it supports any measure intended for placing at the action's core those research and innovation activities jointly decided by industry and research community.

CNR is organized in 102 research institutes, spread all over Italy, and grouped into seven departments: engineering, physics, chemistry, agriculture, medicine, environment, and cultural heritage. Each department is free to follow its own strategic plan, in the framework of the overall mission of the CNR. The DIITET department of CNR (Engineering, Information Communication Technologies-ICT, and Technologies for Energy and Transportation department), to which most of the institutes collaborating in the projects with FC belong, includes research activities on civil and industrial engineering, ICT, system and communication engineering, and applied mathematics. Its approach is to try to promote large, multidisciplinary projects with relevant industrial players, either at a national or an international level, involving the relevant institutes with a variable geometry approach, depending on the industrial needs and topics. In these projects with FC, nine out of 10 participating CNR Institutes belong to the engineering department and one to the chemistry department.

Pre-commercial procurement is considered by CNR an ambitious but efficient instrument to develop new generations of experimental products and services due to its capability to shorten the process "from idea to market" and to leverage further investments in a risk-benefit sharing context. Facilitating cooperation between the scientific community and industries is crucial, and so is providing them with the opportunity to flexibly find the best and appropriate answers aimed at addressing innovation.

Therefore, CNR pays particular attention to cooperation with the industrial system. Actions include joint research programs, research contracts, consulting, licensing and patent releases, foundation of research consortia and spin-off companies, and many other initiatives aimed at enhancing the technology transfer processes to companies and business sectors.

A specific structure is devoted to the technology transfer and valorization of research coordinates and connects the CNR activities with regard to the following topics: marketing research; intellectual property rights protection management and enhancement through the setting up of new technological enterprises; design and implementation of the technology transfer processes.

4. A Glance to the Open Innovation (OI) Approach

After a few years of apparent stagnation, the open innovation theme returned to attract media attention; a quick Google search shows that over 20 million resources mention this keyword. From the point of view of scientific production, it emerges that, in the last 15 years, the number of scientific articles published on the topic grew exponentially, going from 200 in 2003 to almost 1500 in 2016, with numbers certainly grown to the present day. The reasons for this explosion can be found in

the practical fact that the companies realized that the closed innovation process was dead, and that “collaboration” was the new keyword.

The dawn of the concept of open innovation goes back to the definition given in 2003 by Prof. Henry Chesbrough from the Haas School of Business (University of California), when the open innovation approach was referred to as a paradigm establishing the possibility and opportunity for companies to use external and internal ideas and routes to market strategies to take forward their technology [10]. This formulation gives a modern perspective of the open innovation concept pictorially reported in Figure 1.

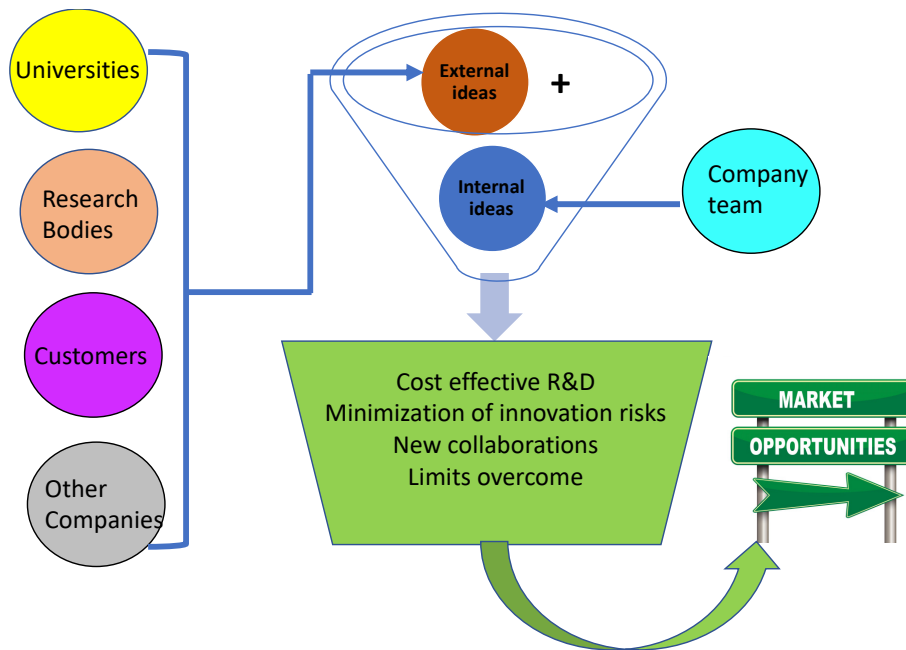


Figure 1. The open innovation concept.

Chesbrough also highlighted the monetary impact of the phenomenon, in terms of percentage of sold products and services tied to the contribution from external technologies and in terms of percent net income generated by technology released to other enterprises [11]. He also put in evidence the impact of open innovation on the new gain opportunities derived from licenses, spin-offs, and sales sessions, as well as the cost savings from exploitation of external development [12] and the yearly investment in collaborative research and development [13].

However, even today, significant barriers persist in the use of the open innovation paradigm. An interesting study conducted on SMEs in developing countries showed how the OI represents an important tool in their innovation process [14,15]. Unfortunately, economic resources and networking capabilities limited by various factors represent, at the same time, an obstacle that SMEs try to overcome by exploiting the opportunities that technology offers, i.e., digital networks.

The fundamental problem of OI is that a number of theories were developed in recent years but there is little in the literature on their consolidation [16]. Open innovation is characterized by quantitative issues, as well as by a dense plethora of additional psychological and motivational qualitative factors. In an attempt to codify a rigorous approach to OI, the authors of Reference [16] ventured into a long theoretical dissertation full of details and psychological and motivational aspects of the key people of this process, who may or not promote the development of this paradigm. In the same study, an attempt was performed to systematically approach the creation of a method for evaluating the motivational effect in the process of technology transfer in a statistical way.

Van Lancker's work [17] tried to evaluate the effectiveness of open innovation for a specific context by analyzing three bio-economy cases tested by a PRI (public research institute), in an attempt to build a formal OI employment approach that may be less variable, at least within a specific sector.

Although open innovation is understandably the only solution for companies to remain competitive over time, there are unfortunately not many scientific studies based on testing different models of cooperation. On the other hand, from a theoretical point of view, the problem was thoroughly investigated.

Since there is "no single best model for engagement" [18], in Reference [19], an overview of the current practices in "corporate–startup collaboration" and "open innovation" in Europe is reported. To this aim, the paper analyzed the experience of 31 European large corporate "innovation leaders" implementing effective corporate–startup collaboration. The work outlines large European corporations that only recently started to concretely engage with startups.

For any type of enterprise (large corporations and SMEs), there are of course advantages and disadvantages in adopting the open innovation approach. Advantages are the reduced costs in research and development, a potential improvement in productivity, an increase in market opportunities, and a potential synergism between internal and external entities. The disadvantages are the possible revealing of protected information, an increasing complexity in the operations control chain, and the need to develop appropriate methods to detect and implement innovation coming from the external co-operators.

Collaboration with research entities is less dangerous than with other firms, as research entities aim at publishing their scientific results, if any, in scientific papers or congresses, and they are not interested in market competition. Nevertheless, the authors in Reference [20], in a study involving over 100 companies (both large and small enterprises), put in evidence that risks, which are mentioned as the more common drawbacks of the open innovation approach, include the loss of know-how (48%), the increase in managing costs (48%), the loss of control (41%), and the increase in complexity (41%). Among additional barriers, the following issues were also identified: hurdles in identifying the appropriate external cooperators (43%), difficulties in balancing ordinary business activities and activities tied to open innovation, and the lack of proper financial and time resources to devote to open innovation management.

In Reference [21], a list of several specific motivations encouraging SMEs to adopt an open innovation approach was given. These motivations can be summarized as follows: (1) cost reduction for internal R&D; (2) possibility to have access to new know-how; (3) possibility to establish collaborative networks for developing or commercializing new products; (4) possibility to acquire external know-how, as well as to sell unexploited internal technical knowledge; (5) possibility to improve the quality of the innovation process management; (6) increased openness to afford risks and increased readiness to react quickly to changing scenarios.

Many SMEs adopt an open innovation approach by collaborating with market-based partners such as customers and suppliers. Drawing on a survey of 146 Swedish manufacturing SMEs, the study in Reference [22] investigated the relationship between SME systematic idea generation and front-end performance and investigated the moderating role of market-based partnership for SMEs. However, the authors underlined that the study had limitations to be considered when interpreting the results because the generalizability of the findings was limited, the study was focused on the influence of systematic routines that relate to idea generation, and the assumption that high levels of systematic idea generation and market-based partnerships lead to high front-end performance needs further investigation.

How SMEs and, more precisely, small firms collaborate with stakeholders in their transition from closed to open innovation was the main topic of Reference [23]. The authors firstly identified factors in the OI literature that could facilitate the collaboration of SMEs with their stakeholders, and then proposed a framework composed of 17 factors grouped into five levers: knowledge, collaboration, organizational, strategic, and financial. Open innovation in small- and medium-sized enterprises has

very different characteristics from that in large companies. In fact, SMEs often do not have substantial resources to devote to the open innovation process; therefore, it becomes very challenging for them to understand how to adapt open innovation processes experienced in large companies. The solution proposed in Reference [24] is to frame SMEs in an ecosystem of reference within which they are perfectly integrated and strongly linked to each other.

The authors in Reference [25] showed how the combination of concepts derived from foresight and foresight networks helps open innovation because foresight provides analysis relevant to the most appropriate technology selection, identifies future customer needs by understanding social and market trends, and addresses some of those challenges identified in the open innovation literature as barriers to effective open innovation. Moreover, the authors highlighted that foresight networks offer open innovation new ideas in innovative collaboration forms from which open innovation new ideas can derive.

By using survey data of open innovation projects from 152 firms, the authors in Reference [26] indicated that the information technology-enabled absorptive capability improves open innovation project performance in terms of innovativeness of new products and their speed to market, but there is not a significant direct influence on performance. They also conceptually and empirically distinguished between ideation and implementation openness, thus developing arguments on how firms can maximize the potential benefits derived by the usage of the external sources experience.

The authors in Reference [27] helped SME managers and entrepreneurs to decide between R&D partners for their innovation strategy, by showing that collaborating with different horizontal R&D partners brings about different innovation outcomes. For example, R&D collaboration with universities has a positive impact on product innovation, but not on innovation performance, whereas collaboration with research centers and other private companies has a positive impact on both product innovation and innovation performance.

The relevance of the different open innovation practices was analyzed for 242 innovating companies in Spain by distinguishing among advanced open innovators, intermediate open innovators, and incipient open innovators [28]. The results of the study indicate that advanced open innovators have a higher performance in product innovation, and that there are no differences among groups in process and organizational innovation.

Open innovation has two modalities: (i) ideas come from outside the company (inbound or outside-in open innovation); (ii) the innovation originating inside the company is pushed outward (outbound or inside-out open innovation). When dealing with outbound open innovation, the role of information and communication technologies (ICTs) and digital platforms in enabling connectivity and collaboration among actors is often neglected; the authors in Reference [29] aimed at outlining the outbound OI phases and exploring the role and capabilities of ICTs in supporting it.

Another form of collaboration is the participation in open data hackathons, which is an important opportunity for public and private entities to collaborate for establishing a win-win situation. Hackathons are events where individuals from different fields cooperate to develop applications that will offer value to citizens while establishing a win-win situation for all involved bodies. Unfortunately, the results of these events are very often abandoned just at the end of the event itself, and the only advantage is the access to open data, which is not sufficient for making business.

Despite the significance of hackathons, the motivations of developers and the challenges of open data hackathons were not deeply studied, and only a few studies focused on the preparation and evaluation of these contests. The authors in Reference [30] investigated the factors that can influence the planning process and the success of hackathons; this paper can be of interest to organizers of hackathon contests as the authors shared practical experience with academics and researchers, thus providing new insights regarding the preparation, the implementation, and the evaluation of these types of contests.

4.1. The Open Innovation in Fincantieri

For several years, Fincantieri started implementing the open innovation approach by developing numerous research projects at several levels (from European to regional) in collaboration with partners, joining or coordinating different consortia in the case of both self-founded activities and public funded programs.

Up to 2015, Fincantieri used to organize one-to-one cooperative projects. The selected partner was, from time to time, academia, a research center, or another stakeholder, involved in developing technological solutions starting from the functional requirements proposed by the industry. The so-called “innovation challenge” is a typical example of this model. The initiatives aimed at promoting a call for ideas on specific topics in different universities (e.g., University of Genoa, University of Naples, or University of Palermo). This kind of approach experienced few limits due to the small dimension of the research groups involved and, sometimes, failed due to a perceived difference in priorities, while developing technologies between the academic and industrial world. In this kind of experiences, the lack of an actor able to close the gap between theoretical studies and industrial applications was the main barrier to an effective achievement. This often caused a loss of potentially interesting solutions in the “valley of death” of the technology development.

Another classical model adopted in cooperative research, especially in public-funded programs, consists of the creation of a wide consortium of stakeholders, sometimes competitors, working with similar, but not identical, goals. Partners in this kind of public-mandated consortia usually have, by design, an equal standing in both managerial and technical matters. The agreements usually identify a “coordinating partner”, which has the role of monitoring and managing the project from a financial/administrative point of view, but which is expected to have only a position of “primus inter pares” on all technical matters. Thus, the coordinator, in our experience, often faces issues in ensuring that projects are delivering their technical results, because it is not expected nor empowered to actually guide the research.

The funding instrument proposed by the Italian Ministry of Infrastructures and Transport (MIT) left room for Fincantieri and CNR to completely reshape the cooperative model. The collaboration between FC and CNR started in 2011 and was reinforced in 2015 in the context of research activities, technological innovation, and training applied to the shipbuilding sector. In fact, the former president of CNR, Luigi Nicolais, and the CEO of Fincantieri, Giuseppe Bono, signed an agreement that expands the strategic partnership agreement, reached at the end of 2011 and, in the fall of 2015, MIT issued a call for proposals, dedicated to shipbuilding industries, in the area of naval engineering and shipbuilding. With this agreement, the CNR was committed to support Fincantieri in the development of research and innovation projects on funds allocated by MIT. In order to not have a too fragmented research team, with a large number of project interfaces, Fincantieri assigned to CNR the role of technical project manager, keeping for the company the overall oversight of the activities by appointing a program management. A group of six large, multidisciplinary, connected research programs, was submitted. The DIITET department of CNR coordinated 10 CNR research institutes and the following three universities: (1) Trieste, Department of Engineering and Architecture; (2) Genova, Department of Civil, Chemical and Environmental Engineering (DICCA), Department of Naval, Electric, Electronic and Telecommunication Engineering (DITEN) and Department of Mechanical, Energy, Management, and Transport Engineering (DIME); (3) Rome Sapienza, Department of Mechanical and Aerospace Engineering, Sapienza University of Rome. All the mentioned universities, involved at various levels in the six projects, were transparent to FC, in the sense that CNR was the only interface to FC, also responsible for the activities carried on by the Universities. Figure 2 shows the hierarchy in the collaboration.

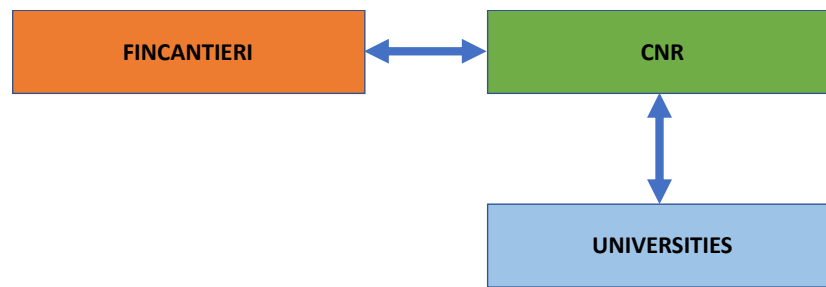


Figure 2. The hierarchy in the collaboration.

The new model (detailed in Section 7) allowed the industrial partner, Fincantieri in this specific case, to actually lead the project and the collaborative effort, with the partners jointly keeping track of the development of solutions, assessing the program deviations from the agreed upon project proposal, and managing difficulties. The sole fact of having the ultimate authority, without having actually to make use of it, allowed the company to coordinate wide teams of academics and researchers in reaching the technical goals that were set at the beginning.

The project was also a unique experience because it assigned clear responsibilities in working at different technology readiness levels (TRL). Universities worked at low to mid TRLs, Fincantieri technical staff was assigned to mid to high TRLs, especially to ensure that external constraints (e.g., applicability, financial viability) were respected, and CNR acted as a transmission chain between the two teams, ensuring both theoretical robustness and real applicability.

This organizational model was conceived for creating solutions able to trespass the “valley of death” and see the light of the market.

In Section 5, the six projects are briefly described.

5. The Six Projects

5.1. E-Cabin

The E-Cabin project aimed at creating a set of advanced technological solutions for cruise ship cabins to improve the passenger experience on board, in the cabin, and in any other ship environment. The solutions are personalized for the single passenger and include (1) a cabin monitoring system, formed of a set of heterogeneous sensors operating inside the cabin, to evaluate the energy consumptions, to schedule the cabin maintenance, to measure a set of environmental values, and to automatically actuate solutions suitable to the specific passenger of that cabin; (2) a set of applications aiming at learning the single passenger’s habits; in this way the passenger needs can be predicted and, thus, his opportunities to socialize, by sharing information through mobile social networking applications, are enhanced, and his participation in the “ship world”, by leveraging augmented reality contents relevant to the cruise, is enriched; (3) a set of applications based on augmented reality to facilitate the movements of the passenger in the ship. The project also includes a study on the comfort perceived by the passenger when multiple disturbing factors act simultaneously, and proposes an energy harvesting solution to power sensors. A dashboard is also provided; it is dedicated to the technical staff of the ship who can visualize the status of each cabin and receive information about all the monitored parameters. The dashboard is designed so as to provide a synthetic, yet at the same time, comprehensive view of the sensed data coming from the different environments by using an intuitive graphical interface. The provided information allows identifying possible outages of a specific sensor, detecting the cabin energy usage with high-resolution accuracy, applying power efficiency measures by detecting the cabin occupancy, and verifying the level of comfort experienced by passengers by evaluating parameters such as temperature, noise intensity, humidity, and air quality in the cabin.

5.2. Technological Platform for High-Efficiency Waste-to-Energy Thermo-Conversion on Board (PiTER on Board)

Currently, new technologies for energy recovery from waste material keep being developed through worldwide actions, aimed at transferring the concept of circular economy into real life and reducing the human footprint on environment and climate. Specific attention has to be given to the applications in off-ground settings, such as on-board energy systems of ships, where sensible amounts of residual matter may be available as a result of the staff or the passengers daily life. Within the frame of low-carbon energy production, waste heat recovery cannot be forgotten, mostly where high-power propulsion systems offer a noteworthy amount of thermal energy (exhaust gases, cooling systems). The project PiTER on Board was focused on the evaluation and development of poly-generation systems for on-board energy use and storage, exploiting the energy content of residual biomasses available during the normal ship operation, and/or using the engine waste heat as primary energy supply to a bottoming thermo-dynamic cycle. Among residual matter, the organic fraction of food waste, waste vegetable oils, and wastewater (sludge) are taken into consideration to produce biogas (via anaerobic digestion), syngas (via gasification), and liquid fuels to use on board. Energy management strategies and CO₂ capture are considered for an optimal integration of each component into the onboard energy grid. Different energy conversion systems (reciprocating engine, gas turbine, etc.) and schemes are evaluated with the aim of identifying the most suitable in the complete waste-to-energy system, whose performance is optimized in terms of fuel flexibility, global efficiency, low environmental impact, and suitability for waste heat recovery and CO₂ capture.

5.3. High-Efficiency Vessel

The aim of this project was to design and experimentally study an advanced energy system able to increase the overall energy efficiency of ships by recovering waste heat from the ship's propulsion system. The combination of organic Rankine cycles, Stirling engines, and latent thermal energy storage systems was assessed. A lab-scale prototype of the energy recovery system was realized. The propulsion system of the ship was simulated with a small diesel engine. Other core components are a thermal storage tank prototype with embedded phase change materials (PCMs), a commercial organic Rankine cycle (ORC) system, and a Stirling engine, optimized for the specific application. The exhaust line of the diesel engine was endowed with a proper design gas-to-gas heat exchanger in order to provide thermal energy to the Stirling engine.

Moreover, the cooling system of the diesel engine was modified to send the hot water from the engine alternately to the ORC or to the thermal storage, in order to maximize the heat recovery. An advanced control tool (ECU) was developed in order to manage and optimize the energy flows as a function of the user demand. Experiments were carried out by simulating a one-week cruise and changing the load of the engine and the hot water request according to typical data. During the simulated cruise, it was possible to recover a relevant amount of thermal energy covering the whole hot water request during the cruise. Moreover, the ORC system and the Stirling engine generated electrical energy for other ship requests.

5.4. Innovative Electric Generation (GEI)

Passenger maritime transportation is undergoing a transition toward greener operations, which is currently pushed by the cruise-line operators. Today, large ships still use electrical power plants where energy generation and distribution are based on well-consolidated but no longer efficient paradigms. Current solutions do not consider the need for optimizing the use of the limited space available onboard, as well as the power efficiency, the consumption of fuel, the environmental impact due to pollutants, and the power quality. To overcome all these limitations, the GEI project proposed new technologies and technical paradigms to be applied on board. The project aimed at developing new technologies for a more efficient and sustainable exploitation of electrical power plant on board, involving the aspects of

electrical generation, electrical power distribution, and electrical energy management. Maximization of the payload and increase of the system safety and reliability were also pursued.

Specifically, results relevant to the project objective were achieved by (1) the design of new Direct Current (DC) and hybrid Medium Voltage Alternating Current (MVAC)/ Medium Voltage DC (MVDC) electrical architectures, (2) the design of a new electrical generation system based on fuel cells, (3) the definition of a new paradigm of distributed generation on board, (4) the development of new energy management techniques for the optimal use of electrical power on board, and (5) the development of new, reliable, efficient, and compact power electronic converters.

5.5. E-Navigation

The E-Navigation project developed a virtual dashboard for using digital information to support navigation, as well as some features of the propulsion control and navigation. These features aim at increasing the number of operations that the ship can perform without the direct intervention of a ship operator. The augmented reality system allowed the digital overlapping of information over the perceived reality. The displayed information comprised routes, speed, possible obstacles on the route and their characteristics, captions of naval vehicles near target ship, and information on control commands of the propulsion. In the project, the functional tests rested on the results coming from a ship simulation platform based on innovative control logics.

The fruition of the augmented information is based on the use of commercial devices, such as smartphones, tablets, or smart glasses, as well as devices that can simulate the functionality of binoculars, since the binocular is a non-invasive tool compliant with a normal activity in the cockpit and, thus, already used in the control cabin. The project aim was also to use it for the fruition of additional digital information. The realized system allowed the transmission of information, displayed on the virtual bridge, toward the ground station, i.e., a remote-control information system that supports the on-board operator in the execution of some tasks, thanks to the help of ground operators.

5.6. Secure Platform

The Secure Platform project had two general objectives: (i) to develop an advanced security system for the protection of on-board passengers and personnel, able to improve security during ordinary situations and to make more efficient the crisis management; (ii) to realize a completely novel system for search and assistance of the man overboard.

The abovementioned objectives were pursued through the scientific–technological achievements sketched below. The development of an advanced system for the protection of passengers and crew was based on the following:

Computer vision techniques operating in indoor and outdoor environments, based on cameras (visible, thermal), for people and goods tracking;

Multisensory biometric recognition techniques (fingerprint, vocal imprint, face recognition) for selective access to ship areas;

Methodologies and technologies for the detection, localization, and tracking of people within a closed environment based on radar systems.

This on-board sensing system was supervised by an ICT platform able to collect, integrate, and provide the results through a friendly presentation layer. The ICT platform collected not only the multi-sensorial data but even the alarm signals from the technological infrastructure present on the ship.

The development of an advanced system for assistance and rescue of man overboard was based on the development and integration of the following:

Air drones able to (i) give the alarm on overboard man at sea, (ii) initialize the search of a man overboard, as well as in the case of a non-cooperative person, (iii) execute an automatic launching system of one or more drones for localization of man overboard, and (iv) activate the recovery operation of the man overboard;

Autonomous marine unmanned robotic vehicles, integrated with the man overboard recognition and tracking subsystem, for the rescue of the person.

6. Barriers in Organizing a Shared Research and Innovation Program between Academia and Large Industries

The collaboration between different institutions is not very simple because there are often different goals, interests, and different visions. In order to build solid and productive collaboration, it is firstly necessary to change mindsets.

The industry has to be ready to spend some time to explain to researchers its needs, to pass them information necessary to reach the goals, and to be open to give trust to people that work with research. For this part, research institutions and academia have to accept that respecting economical rules is fundamental because, otherwise, a large industry cannot sustain the effort of the research. Another barrier is the will to be the first to make a discovery in order to obtain the intellectual property; this is not the only way to obtain profit, as the real key to have profit using an innovative idea is to build a good business model.

Many examples of collaboration are discussed in the literature. In Reference [31], Saguy said that it is very important that academia's members are involved in industrial development in order to better understand industrial needs but, at the same time, the industry representatives have to enter the teaching staff to help academia in building opportune flows of know-how changes.

The fundamental idea is that, in order to start this open innovation approach, the boundaries of the research would have to be permeable to the flows of knowledge coming from industry and vice versa.

How We Overcame the Boundaries

In this paper, we demonstrate that the collaboration among different organizations with different aims can successfully work. The basic point is to respect the different visions, promoting common projects whose results can be used on several fronts and finding the right balance between assuring a competitive advantage for the company, and granting research institutions the possibility to advance their scientific programs and convey their results to the broader scientific community.

The business model proposed and implemented by Fincantieri was fundamental for the success of the aforementioned six projects. It envisaged a side-by-side collaboration of business experts and academics. They dealt with research issues and industrial issues from time to time, and every time they brilliantly solved these problems.

The sharing of a goal and the accountability of all the parties involved in achieving it in the best way underpinned the success of the aforementioned projects.

Obviously, successful experiences are very important in order to develop solid communication channels that are lasting over time. In these projects, the direct relationship among the actors created the opportunity to know each other and to appreciate each other's qualities, a fundamental element with a view to the SIW (sharing is winning) model [31]. Therefore, it is necessary that these collaborations with dedicated and long-term programs become more and more common practice in order to allow a more and more widespread integration. Of course, this is a long process and not without obstacles, but public research institutions, such as CNR, are facilitated in this process by a historical vocation focused more on applied research than on basic research and, as such, closer to the industries.

7. The Open Innovation Model Adopted

7.1. The Management Structure

The management structure proposed by FC and put in place during the six projects' envisaged lifetime is shown in Figure 3.

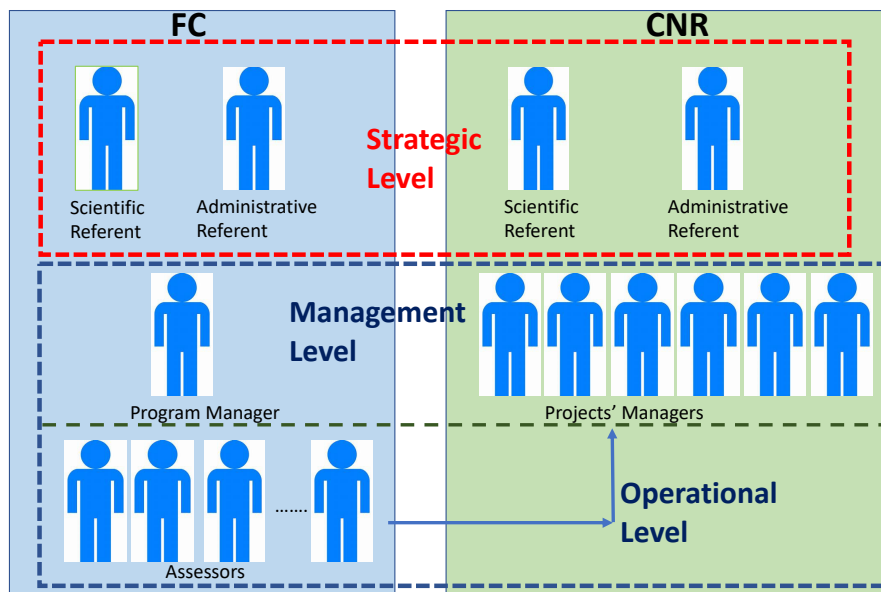


Figure 3. The management structure adopted.

The model consists of three levels: (1) the *strategic level*, where technical and administrative decisions are taken; (2) the *management level*, where the progresses of the individual projects are reported; (3) the *operational level*, where the technical activities of the projects are carried out with the support of FC technicians. The roles are described below.

On the Fincantieri side, the roles were as follows:

- One administrative referent for administrative businesses;
- One scientific referent, i.e., the FC scientific interface to CNR for the entire program;
- One program manager (unique, for all the six projects). His task was to ensure that the development of the activities carried out in each of the six projects was consistent with the timing, objectives, and costs established. It represented the FC interface with the administrative reference, the scientific reference, and the six project managers of CNR;
- A certain number of project assessors, with at least one assigned to each project. The role of the assessor was to support the relevant CNR project manager by providing indications or data from FC.

On the CNR side, the roles were as follows:

- One administrative referent;
- One scientific referent, i.e., the CNR scientific interface to FC for the entire program;
- Six project managers, one for each of the six projects; each of them was responsible of the related project activities.

7.2. Document Management

For each project, the basic document was the Statement of Work (SoW), which described the technical–economic activities of the single project. In order to prepare a correct formalization of the processes, the document management of each project included the following documents:

- Project requirement list. For each project, this was the list of the requirements expressed by FC to ensure the transfer of project results in the product. It was written by the FC program manager on the basis of meetings with the assessor, and it was validated by both the fc program manager and the CNR project manager. It was integrated on the basis of the requests of the FC program manager or the CNR project manager.

- Monthly objectives list. This document contained the detailed description, consistent with the SoW, in which the objectives were defined, measurable monthly for the three months following the quarterly meetings. These goals were not economic but technical–administrative and could be approved. They were defined by each single CNR project manager and validated by the FC program manager.
- Project risk register. This contained the list of risks emerged during the project course, together with a management strategy of the risk itself. For each project, it was written by the FC program manager in agreement with the relevant CNR project manager.
- Project claim register. This contained the list of cost items declared by the specific CNR project manager not accepted by the FC program manager for lack of technical–economic consistency or for other reasons. The claim was raised by the project manager, and then the list was drawn up by the program manager and notified to the project manager.

7.3. Monitoring and Control

For each project, the monitoring and control phase was realized through a temporal sequence of activities, shown in Figure 4 and briefly described below.

Quarterly, the project manager created a report of the project, in preparation of the quarterly meeting, which was established and chaired by the program manager (with the scientific referent, the project manager, and the project assessors). The project manager and the program manager qualitatively verified the progress of the work, based on the items of the monthly objectives list.

The project manager provided the program manager with detailed documentation on the individual cost items associated with the volume of activities carried out by the project consortium (both CNR institutes and universities involved). The program manager checked the consistency between the technical activities performed and the declared costs, accepting the costs declared by the project manager or enrolling a claim, issued by the assessor, in the project claim register. The project manager and the program manager verified the economic trend with respect to the project budget, net of the costs for which the claim was registered. The project manager and the program manager had to agree on any possible change to the statement of work. The program manager confirmed the project requirements list and updated the project’s risk register, if any risk was identified. The project assessor validated the project deliverables or indicated how and why they had to be modified, integrated the project requirements list, if necessary or if requested by the project manager, approved the monthly objectives list for the next quarter, checked the technical consistency of costs, validating the activities, and issued a claim in case of inconsistency.

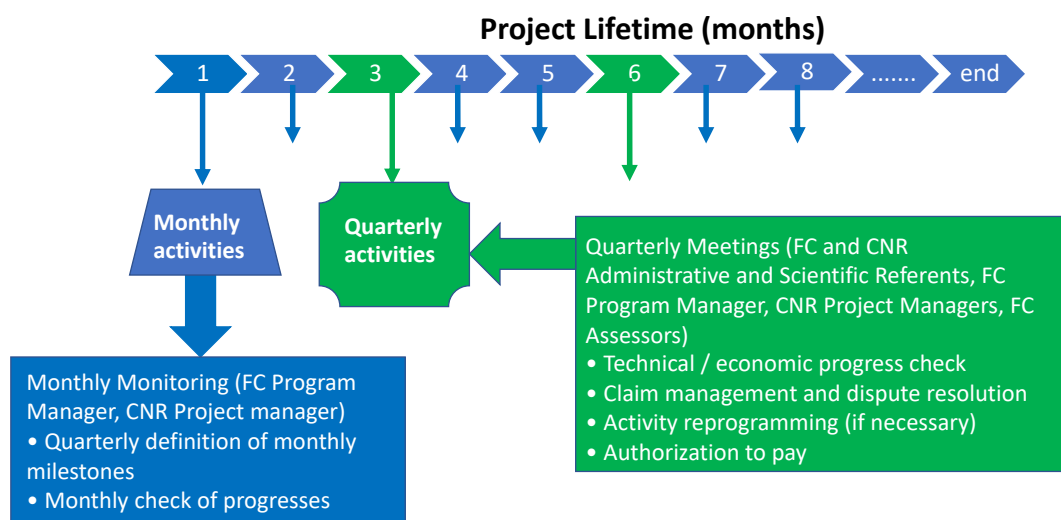


Figure 4. The monitoring and control actions (for each project).

In the same quarterly meeting, for each project, the FC administrative referent, together with the CNR administrative referent, resolved any disputes over the acceptability of costs.

8. The Results of the Implementation of the Project Management Model

The implementation of the above-described management model allowed an effective progress of the planned activities throughout the lifetime of the projects. As an example, Figures 5–10 show the status of the projects’ advancement at the Q7 quarterly meeting, represented in terms of both S-curves ((a) in the figures) and Gantt diagrams ((b) in the figures), where the gray bars represent completed activities. In particular, the S-curves make it possible to visually track the progress of the projects over time, substantiating their historical development from the beginning to date. As a matter of fact, the S-curve evaluation permits project managers to have a global view of the project growth, and to timely detect possible criticalities such as deviations from planning, and other potential problems that could have an adverse impact on the activities if no appropriate action is taken to remedy them. In the S-curves, the blue line shows the ideal trend of the project, while the red line shows the current trend; the quarters are shown as the abscissa, while the expected payment is shown as the ordinate.

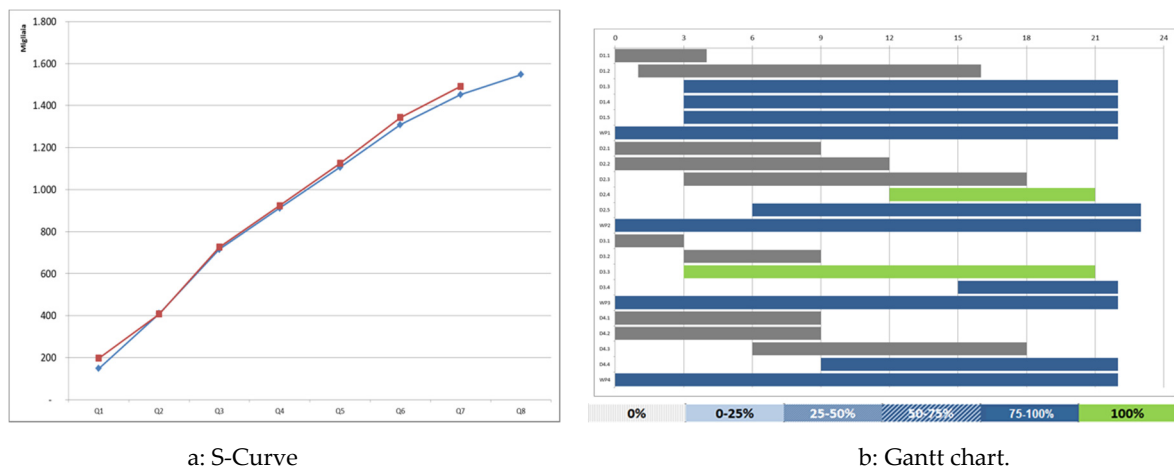


Figure 5. Innovative Electric Generation (GEI).

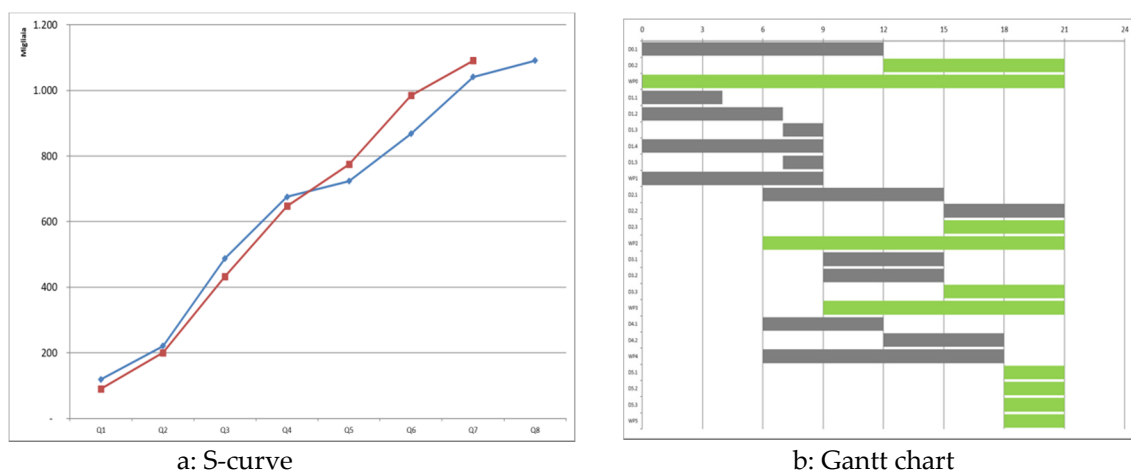


Figure 6. E-Navigation.

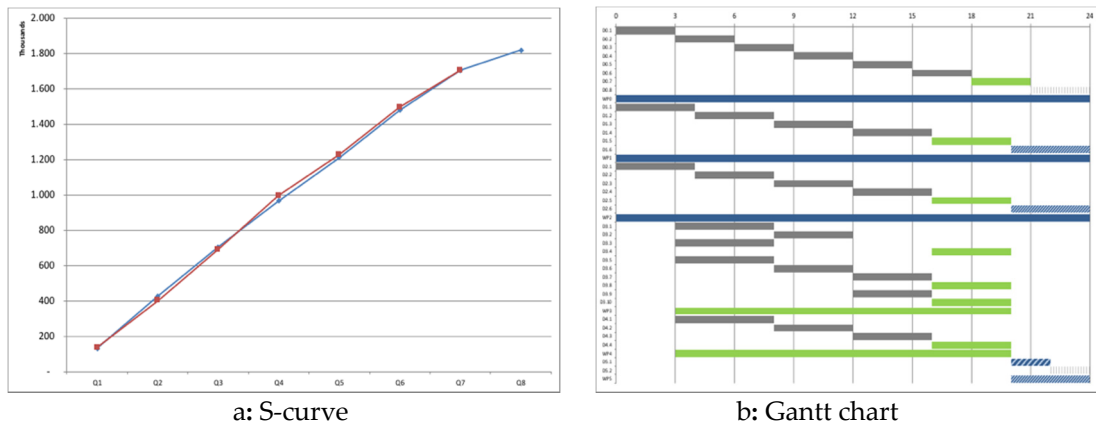


Figure 7. E-Cabin.

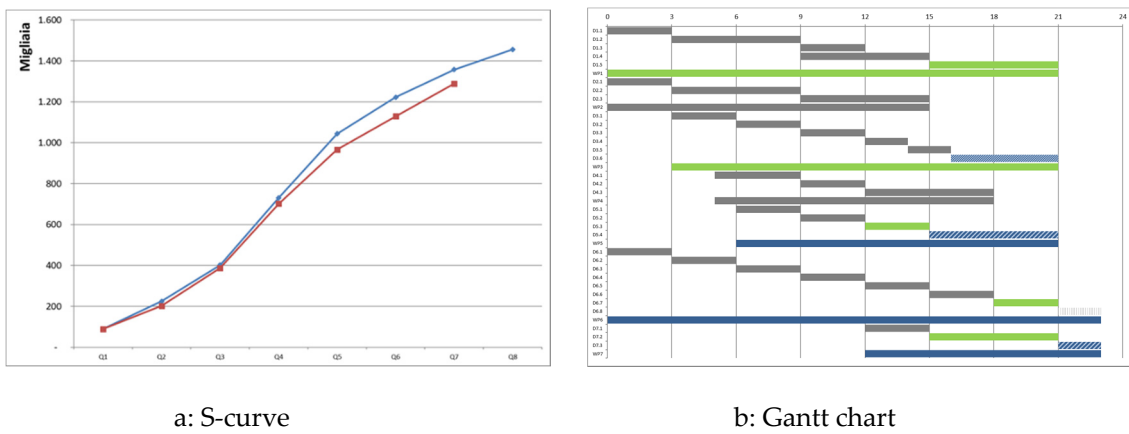


Figure 8. High-Efficiency Vessel.

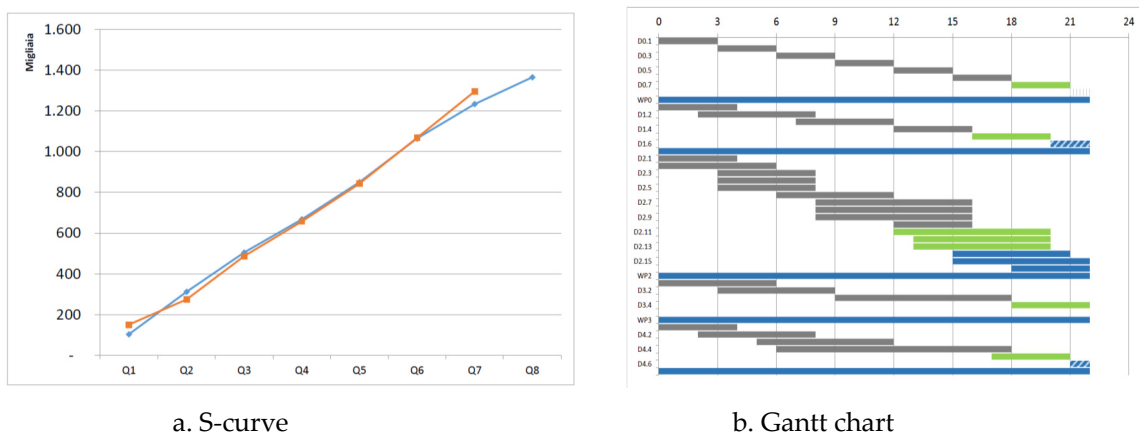


Figure 9. Secure Platform.

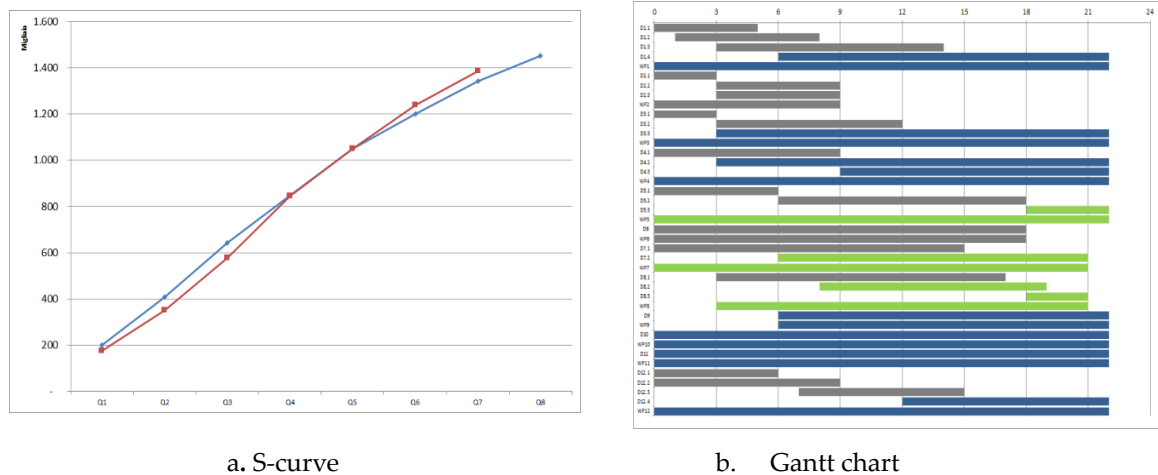


Figure 10. Platform for High-Efficiency Waste-to-Energy Thermo-Conversion (PiTER) on Board.

9. How the Collaboration Created Value for Both Fincantieri and CNR

During the collaboration between FC and CNR, new services were developed in each of the six projects, confirming what was asserted in Reference [32], i.e., the importance of interdisciplinary collaboration for the successful development of new innovative services. Innovation is a major point for reasonable advantage and, in the last two to three decades, there were many studies on innovation in products, services, information technologies, processes, and systems [32,33]. Innovation in services increases the quality, contributes the skills of new services, answers to the requests, creates new services, and can increase the competitive advantage because it contains the knowledge of customers and employees. It also implements new markets for services and it promotes competitive differentiation between competitors. Generally, the term “innovative services” was used in the literature to describe new or improved services, as well as the necessary strategy and processes to create new services using new knowledge, processes, and technologies [34]. Kitsios and Kamariotou analyzed 178 papers that were categorized by discipline and method, implementing a structured methodological framework to identify existing knowledge. They observed the notion that new service development (NSD) is something that just “happens”, and it can be used as a tool to raise awareness about organizational characteristics that need to be taken into consideration when developing new services [35]. However, the lack of strategic alignment with the necessary resources is the main reason of the low percentage of successful in developing new services, as asserted in Reference [36]. Kitsios provided an analysis of the reasons that often lead to the introduction of new services in a business context that is not successful despite promising expectations. It is in fact a sort of overview that wants to establish the balance between the strategies for introducing new services, the contribution provided by information technology in this process, and the alignment of new services to be introduced with the corporate strategy.

The model here presented is a perfect example of harmonious balance between the inbound and outbound open innovation process, which is essential for the sustainability of the paradigm. The ideas from outside (CNR and universities) were conveyed inside Fincantieri and combined with their internal ideas to generate innovative outcomes, for the benefit of both Fincantieri and the research units. Moreover, all resources necessary to successfully complete the program of the six projects were available, as, in total, there were over sixty researchers involved, thus guaranteeing the alignment between the necessary resources and the program to carry on.

For CNR, the added value of the collaboration with Fincantieri relied on the following achievements:

- Development of new services ready to be put on the market and appealing from a research point of view;
- Publication of papers in both technical journals and conference proceedings;

- Participation to symposia and forums including industrial stakeholders;
- Better understanding of the naval industrial needs and challenges;
- Higher visibility of its research skills within the industrial community;
- Contribution to the competitiveness of Fincantieri.

Moreover, the inherent structure of the projects, which comprised several university-based research groups, promoted the establishment of productive and inspiring scientific dialogue on the different technical areas involved in the six projects.

The cooperation drove Fincantieri toward two separate achievements, even if strictly correlated.

The first one was related to technological development. All six projects reached relevant results in terms of new technologies, innovative solutions, and prototypes ready to be transferred to the market in short time. The second one was the validation of this novel approach for managing, at the same time, several cooperative projects. The technical results and the quality of the collaboration established during the activities proved to Fincantieri that the model adopted is sound and robust, and they can help to overcome the typical barriers identified in the previous cooperative experiences (mentioned in Section 4.1), as well as be re-applied in other complex management activities.

The projects were highly beneficial for Fincantieri, allowing the company to achieve the following:

- Prototype and develop several ideas aimed at long term development, ring-fencing them from the turbulences of day-to-day activities;
- Benefit from a staff that could professionally manage complex low TRL (technology readiness level) projects while, at the same time, benefitting from a result-oriented approach;
- Create functional mock-ups and three-dimensional (3D) models, which were used to show the results of the activity among the business units;
- Create intellectual property and gain competitive advantage in all the areas covered by the collaboration;
- Put designers and technical staffers in touch with peers from the research environment, easing idea circulation and assumption validation, extending beyond the specific scope of each project;
- Collaborate in framing new joint initiatives to further develop the results obtained in the projects.

The Open Innovation Business Model in Fincantieri

A business model allows ideas and technologies to become valuable economic outcomes. An open innovation business model is a powerful organizational model of innovation and, by reducing the costs of the innovative research development, it can generate extra revenue by monetizing technologies through license agreements and/or spin-off activities, when the technology cannot be adopted profitably in the product market of the company, thus leading to a better financial performance [37]. In the Open Innovation model here presented, Fincantieri used the background and the knowledge of CNR to develop innovative solutions in six different aspects of naval activities, which led to the realization of working prototypes that gave Fincantieri a competitive advantage in the naval sector by identifying relationships of interaction and cooperation with suppliers and customers, according to the strategy of the company. Fincantieri, for fostering the adoption of new technologies on-board of its products, adopts a strategy of developing them up to high TRLs, and then makes them available to the technical and commercial staff as “off-the-shelf” products that can be added to the products that are being developed or to commercial offers. This strategy was also applied to the innovative solutions discussed in this paper.

10. Conclusions

Today, open innovation is a very trendy topic that improves the synergy among different entities for enlarging the market opportunities. This paper presented a successful example of management between a large research entity (CNR) and a large enterprise in the naval sector (Fincantieri), according to the open innovation paradigm.

Up to 2015, Fincantieri used the open innovation model based on one-to-one cooperation with academia, a research center, or another stakeholder but they experienced that this kind of approach had limits due to the small dimension of the research groups involved, which also sometimes had an impact on the results. Even the creation of a wide consortium of stakeholders working with similar goals has its limits because partners usually have, by design, an equal weight in both managerial and technical matters. The coordinating partner, which normally is selected in such an open innovation model, has just the role of monitoring and managing the project from a financial/administrative point of view; however, from a technical point of view, they are equal to the other partners. Therefore, if the consortium does not work suitably, the coordinator has no means to guarantee the success of the collaborative research.

The model here presented proved to be a real success because Fincantieri actually led the six projects as if it were a single project, monitoring the collaborative effort, keeping track of the development of solutions, assessing the program deviations from the agreed upon project proposal, managing the difficulties, and collaborating with CNR by putting at the disposal of the CNR researchers the specialistic naval background necessary to carry out the projects that the researchers did not have. The sole fact of having the ultimate authority, without having actually to make use of it, allowed the company to coordinate wide teams of academics and researchers in reaching the technical goals that were set at the beginning.

The management model adopted by Fincantieri and presented in this paper proved to have no limitations, and it was so profitable that Fincantieri decided to apply the same model in another innovation project devoted to developing technologies that can prove to be disruptive for the maritime industry. In fact, the company recently started the TECBIA (environmental sustainable technologies for on-board power production) project, financed by the Italian Ministry of Economic Development, which has the goal of building a prototype of a small boat propelled thanks to the energy obtained from fuel cells. In this new project, Fincantieri is replicating the same tools and methodology successfully employed for the six joint R&D projects recently completed. The open innovation model adopted is accompanied by a business model that gives to Fincantieri a competitive advantage in the naval sector with respect to other competitors.

As a final consideration, we can say that one aspect that was little considered in the open model described is the presence or absence of SMEs in the cluster; in subsequent experiences, it would be interesting to understand how the presence of SMEs in the open innovation process can increase/modify the chain of the value to and from the big company.

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