Corso di Laurea Magistrale in Management e Controllo dei Processi Logistici

24/7 Ports
Perspectives and challenges through the 5G revolution

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1 Thesis content and objectives

The logistics and port sector is facing enormous changes caused by the penetration of information and communication technologies into operational and management processes. In this sense, the Ports of the Future (increasingly “smart” and interconnected) are turning into “C-Ports”, real hubs for the creation of value and knowledge based on technology transfer.

Information and communication technologies enable a set of new digital services (“user-centric”, innovative and based on standard architectures, networks, services and data) that allow the continuous improvement of operational and environmental performances.

The adoption of these innovations for the management of maritime and logistics-port processes allows to create the C-Port. It was therefore considered necessary to define a C-Port vector for the evaluation and ranking of ports in relation to their actual and evolutionary "smartness".
The thesis focuses on the Case Study of the Port of Livorno, which, through this approach, is following the so-called “Smart Landscape” paradigm.

Through the creation of an industrial 5G network, the port is proposing itself as a national reference for the experimentation, implementation, and assessment of new digital services enabling a 24/7 Port.
2 The logistics sector

2.1 The evolution of logistics

World is moved by logistics, every business and organizational process is permeated by it.

Since the 1960s, the term "business logistics" has evolved due to the increasing complexity of supplying businesses in a globalized supply chain. From the business point of view, logistics may have either an internal focus (inbound, or “industrial” logistics) or an external focus (outbound logistics, or “transport and distribution logistics”), covering the flow and storage of materials from point of origin to point of destination.

The main logistics processes include transportation, purchasing, inventory management and warehousing and the organizing and planning of these activities [1].

Traditionally, logistics has been considered a "non-core process", an activity that does not contribute to the value creation process, in fact it was considered a process based on downward competition and where
investments had a tendency to be “limited”, if compared to those resources allocated for those main "core" processes.

Since the 1980s, with the new “lean manufacturing” paradigm, logistics has taken on a strategic key role: logistics processes have been redesigned with a view of creating value and eliminating all those wastes imputable to inefficiencies and lack of organization.

In this way, logistics processes are becoming increasingly automated and optimized, thanks to the contamination of ICT and industrial statistics.

The concept of "lean", based on the streamlining, digitalization, automation and efficiency of the logistics chain upstream and downstream processes can also be applied to other sectors, firstly, to distribution and maritime logistics [2].
2.2  The Italian Maritime sector

Logistics processes digitalization represent a more than relevant challenge in the national and international panorama, then every single step or procedure is involved in this particular revolution. In this sense, ports play a fundamental role in the digital transformation.

With reference to 2020, Figure 1 shows a pie-chart describing freight traffic statistics in Italian ports (in tons).

![Figure 1 - Italian Ports freight traffic, 2020](image-url)
2.2.1 Ports classification

There are various types of ports, depending on their main activities they are distinguished in:

1. Commercial and industrial ports;
2. Tourist ports and marinas;
3. Military ports.

The first category is the one we will focus on. A commercial port is made of various elements, such as internal and external docks, port cranes, warehouses, storage yards, terminals, light towers and other components. The dynamics of the sector, as well as the characteristics of the operators and the vessels employed, change substantially according to the freight characteristics.

We must distinguish bulk traffic from “unitized” cargo. We can define "bulk transport" as "the transport of goods, of any kind and in any physical state, transported without packaging". This segment, which includes liquid and dry bulk, represents the most significant share of world maritime traffic. The dry bulk segment includes all minerals, coal,
wood products and cereals. On the other hand, liquid bulks traffic includes the handling of oil and petroleum products, liquefied natural gas and chemical products.

Conversely, when we consider unitized traffic, the product segmentation refers not so much to the goods characteristics (in this case we are referring to semi-finished and finished products), but to the use of transport modules, containers and swap bodies, which contain heterogeneous goods. In terms of transported tons, this market segment relatively represents a smaller share of the global freight traffic. However, considering the heterogeneity of containerized goods, tonnage is not the most appropriate measure for analyzing this market segment dynamics and impact. A more suitable volume size, the TEU (Twenty-Foot Equivalent Unit)\(^1\), is used.

\(^{1}\) According to the international measuring system and the International Standard Organization, one TEU corresponds to a twenty-feet ISO container.
For the unitized loads transportation, we can have two different loading methods: "Lo-Lo" (Lift on-Lift off) and "Ro-Ro" (Roll on-Roll off).

In the first case, also known as “transshipment”, the loads are taken-off from the ship and loaded on another ship or on the berth, ready to be loaded on other means of transport (such as trains or trucks), and then intermodality is achieved without cargo-breakage. In the second case, instead, the operation of load or unload happens without mechanical means, because cargo is already placed on trailers or semi-trailers. While Lo-Lo transport uses ad-hoc container ships, Ro-Ro traffic needs ferries (Ro-Ro or Ro-Pax ships) [4].

Maritime transport is a key factor in the economic and industrial development of the country, so it is important to allocate resources and investments in specific research and innovation plans, with the aim to enable process improvement. In this sense, digitization and ICT technologies represent a precious support.
2.2.2 The Italian Port Authorities (AdSPs)

The Legislative Decree No. 169 of 2016 (Published on the Italian Official Journal on August 31, 2016), established the seventeen Italian Port System Authorities (AdSP). The Italian AdSPs play a strategic role of guidance, planning and coordination of their system of ports, or "port network", so it is more appropriate to talk about “Port Network Authorities” [5].

The port system is a pillar of the national economy, both in absolute terms, as it strongly contributes to the national GDP, and from a logistics, touristic and industrial point of view, as freight, passengers and materials access point.
2.2.3 The port communities

From an economic point of view, the port digitization process generates added-value and this has an important redistributive effect for all the stakeholders involved in the port system.

When referring to the actors of port logistics, taking into account the Port Authority only it is a restriction, in fact, it is more appropriate to talk about "port communities", which includes all the stakeholders, or “personas”, which are closely related and involved in the port environment. Hinterland companies, road and rail infrastructures, freight forwarders, shipping agents, terminal operators, shipping companies, freight villages and, finally, citizens, must be taken into account while defining the research and analysis area and the business models subjects. Port services and port infrastructures must be designed according to the personas’ needs and expectations.

The entire port community benefits from the port’s innovations in two different ways:
1. Directly, in the case of clear improvements in logistics processes in terms of efficiency and optimization, improved employment in the port hinterland and GDP;

2. Indirectly, in terms of improved quality of life.  

With reference to the research and development activity, it is important to define the "user-personas" involved in the processes. Personas are defined as “all those end users who cover specific key roles in the production and logistics processes and who in some way come directly into contact with the innovative service developed by the technological hub”.

The research and development activity is, in fact, defined and analysed also in relation to the impact on the end user, who in a certain

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2 In relation to this last point, for instance, a system of optimization of the yards, based on 5G technologies, can also improve air quality thanks to the reduction of the ships stop time at berth and the port systems optimization (avoiding, first of all, empty trips) and the reduction of accidents.
sense plays an active and proactive role, also with regard to the
definition of requirements.³

2.3 *The role of logistics in the Italian economy*

It is fundamental to deepen the logistics sector in the Italian context. According to the *TTS Italia report* about “*ITS applications for a more efficient logistics*” [6], logistics plays a fundamental role in the economy of our country: it is currently a sector characterized by approximately 100,000 companies that employ 1.5 million people and generate 85 billion euros of turnover (equal to 9% of the Italian GDP). This sector is also characterized by numerous critical issues and inefficiencies, today estimated at 70 billion euros per year (of which, more than 30 billion, can be attributed to bureaucratic burdens and delays in the digitization), and which risk gets worse in case of emergency situations like the Covid-19 outbreak. Therefore, we feel a strong need

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³ The concept of “*personas*” will be taken up and developed in a more detailed way in paragraph 5.2, in respect of the research and development areas.
to recover the logistics sector decrease of turnover connected to inefficiencies, by promoting ad-hoc initiatives of increasing the massive use of the new ICT technology.

In this regard, the European Commission initiative for the digitization of logistics, “EU Regulation 2020/1056 of 15 July 2020”, has the purpose of creating a single framework for the freight and transport electronic data interchange. Data must be exchanged on dedicated and trusted platforms by certified logistics operators. This initiative is designed to complete and integrate a fairly wide and consolidated regulatory framework that should further promote the digitalization of the sector, as already happened with the “ITS Directive 2010/40/EU”, a ITS milestone, that Italian Ministry of Infrastructure and Sustainable Mobility (MIMS, formerly MIT) has received with the “ITS Decree of 1 February 2013”, the “Delegated regulations of the ITS Directive 2010/40/EU”, etc.
2.3.1 “Next Generation EU” (Recovery Plan) and the logistics sector

For the recovery of the European economies, devastated by the COVID-19 pandemic crisis, "Next Generation EU" (also known as "Recovery Fund") represents a maxi plan of 750 billion euros. Italy will have access to a share of 27.8% of the total amount, which is equivalent to 209 billion euros. The payment of the funds will take place over a period of six years.

The heart of "Next Generation EU" is "Recovery and resiliency facility", based on the dual objective of stimulating investment for the recovery of aggregate demand ("recovery") through reforms that increase the sustainability of European economies, with the aim of making them more adaptive to change in the years of recovery from the crisis ("resiliency").

According to the plan requirements, each state must allocate at least 37% of spending on climate and energy issues and at least 20% to the digital transition.
From a European perspective, the logistics network infrastructural upgrading represents a strategic way to make Italian ports increasingly essential, since they represent the link between the Mediterranean Sea and Northern Europe.

The explicit objective of Next Generation EU is to restore the European economy: it has the ambitious goal to increase the individual European countries trustiness, making them more attractive for investors’ post-crisis projects.

Logistics and transport are two sectors of primary interest for post-crisis economic recovery and for consolidating the level of resilience of global supply chains.

Through a forward-looking use of resources from the Recovery Fund, Italy could exploit its strategic position as a hub in the Mediterranean Sea, in fact this is an opportunity to "change strategy" and become a competitive country, able to attract the attention of international investors [7].
The PNRR program is structured into six structural "thematic areas":

1) Digitalization, innovation, competitiveness and culture;
2) Green revolution and ecological transition;
3) Infrastructures for sustainable mobility;
4) Education and research;
5) Inclusion and cohesion;
6) Health.

With regard to intermodality and integrated logistics, the “National Recovery and Resilience Plan” (PNRR) includes the allocation of 3.68 billion euros for the strengthening of the Italian port network system, mainly through a connection improvement between the national main maritime hubs and the national railway network. In particular, the PNRR (section 3.2 "Intermodality and Integrated Logistics") provides the following reforms of specific interest for the digitization of logistics:

- To realize the "Customs Single Window", which will allow interoperability with national databases and the coordination and control of the customs activities;
To make the *Port Community System (PCS)*\(^4\) of each Port System Authority compatible with each other and with the National Logistics Platform (*PLN*) managed by *UIRNET*;

To simplify the logistics procedures by the digitization of documents, with particular reference to the adoption of the electronic waybill (*eCMR*) in the freight forwarding operations.

\(^4\) Regarding a standardized Port Community System, the Port of Livorno has implemented the TPCS (https://tpcs.tpcs.eu/login-en.aspx). This platform digitalizes and simplifies the import and export operations data flow.
3 Port logistics processes

3.1 The “Port-Centric Logistics”

Logistics processes facilitate production products management and their handling. In particular, logistics processes should be related to the main production phases in relation to costs, timing and, finally, quality.

If logistics operations are successfully coordinated by companies and organizations, processes can be tracked and analyzed through production, warehousing and storage, consumption, and availability. As a result, a truly efficient logistics workflow depends also on the correct geographical location of all assets in an organizational context.

The logistics process phases seek to identify the best solution for the production and distribution of goods by evaluating how markets will use these products. As part of this process, a company should always consider the product location and analyze all the factors associated with them. This includes all the times and costs linked to production, personnel, consolidation and deconsolidation, storage and space. In
fact, a company should also take into account such factors which can have an influence on production quality and on transportation efficiency between hubs.

Ports are crucial logistics hubs, as they connect different markets and various economies, so a new “Port-centric logistics” (PCL) paradigm, referring to the transformation of the port into an innovation space, is now taking momentum. To address current challenges and prepare for future ones, ports and terminals must transform their operations by making them more sustainable and promoting collaboration. This means making data more available, utilizing yard spaces and increasing throughput, as well, all while reducing emissions.

Depending on the firms positioning in the supply chain, PCL could mean something different, according to the magnitude of ports operations. A port planner can consider it as a way to make the most of abandoned lots in the proximity of port and city. However stakeholders choose to act, ports understand the need to strengthen their logistics infrastructures.
Ports are driven by macroeconomic events. The growth of the global economy, as well as the collapse of COVID-19, has increased the amount of cargo transported by sea and through ports. Shipping companies have reacted to the environment change by extending their fleets and by forming partnerships to optimize services. Also, in the case of A.P. Moeller-Maersk and others, they invested heavily to become end-to-end integrated suppliers, as parts of an efficient, integrated supply chain. This concept is not limited to carriers: terminal operators increasingly feel themselves as enablers of global trade operations, and not constrained to the port they belong to.

This emphasis on connections is the key to PCL, because as trade is getting faster and wider, it also needs to turn "smarter" [8].
3.2 Critical issues and “bottlenecks”

Trade depends more on trade facilitation and less on output: logistics and transport, together with ICT, are key enablers, as they facilitate the integration and development of the global economy.

There are several factors affecting port logistics flows, namely the already mentioned increase in international trade operations, which is one of the main causes of port congestion. It follows that port capacity is rationalized in precise time-slots. Overcapacity and undercapacity issues may occur.

Due to a disruptive growth of containerized maritime cargo flows, ships have become bigger and bigger, as well as technologically sophisticated. In this sense, infrastructures like canals (Panama, Malacca, Suez), port docks, terminals and cranes must be adequate, as giant vessels require deep-water ports. Furthermore, due to climate
changes impact on water dynamics, ports are often exposed to sand silting and necessitate specific dredging operations.\textsuperscript{5}

Safety and secure matters, as well as environmental protection laws can affect port productivity and efficiency.

Shipping market cycles are characterized by irregular peaks and throats. Demand is volatile, quick to change and unpredictable; supply is ponderous and slow to change [9].

Trade is also subjected to the “bullwhip effect”, which refers to the amplification of demand shock along the supply chain.

\textsuperscript{5} Relocation of sediments sets logistics and environmental issues, with the urge to minimize economic impacts.
Figure 2 explains bullwhip effect with a diagram. Quoting the author, “According to the bullwhip effect, customer demand should be the most stable variable within the supply chain. Once this variable becomes volatile, the rest of the supply chain becomes even more unpredictable, and each upstream player within the supply chain must rely on some derivative form of erratic data” [10].

![Bullwhip effect in supply chains](image)

In the past, due to inadequate land transportation infrastructure, state borders, tariffs, and other barriers to trade, ports were in the most part insulated from competition, each only servicing its captive hinterland. At the same time, ports were also being viewed by governments as "growth poles" and "regional development hubs," providing added-value, employment and economic boosters.
With the exception of some developing countries, port infrastructure was developed in advance of existing demand, in the hope that productive activities would expand as a natural consequence of infrastructure development. Thus, port development was considered a public investment, even today the prerogative of the State, and investment costs did not have to be recovered. In addition, port fees were kept low to facilitate international trade.

Small volume logistics and distribution and low usage of transportation means put excessive requirements on infrastructure, whose usage must now include the externalities of transportation. New systems are needed to minimize the distances and environmental impacts of transportation [11].
3.3 Risk mitigation

Laissez-faire, together with Political Liberalism and Globalization have led to the creation of global supply chains and free trade zones. This has led to the rapid growth of the logistics industry, which has also defined a new paradigm for the global cargo insurance market.

When considering risks and the mitigations that come with them, we need to understand the causal elements, which can be defined as "unpredictable," including catastrophic damage and human error. This is the reason why financial departments and risk managers, are today called upon to carry out an intense work of risk assessment, which requires interaction with suppliers, so as to be able to well identify the most appropriate complete coverage of all risks for their own type of logistics operations along the supply chain. The choice of the most suitable insurance coverage will safeguard clients from all types of damage and loss. Several risk factors must be identified and measured.

The taxonomy of risks in port container terminals is shown in Table 1, according to the five main risk categories [12].
Table 1 - Taxonomy of risks in a container terminal [12].

<table>
<thead>
<tr>
<th>RISK CATEGORIES</th>
<th>RISK SUB-CATEGORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>▪ Ship collisions;</td>
</tr>
<tr>
<td></td>
<td>▪ Grounding and sinking;</td>
</tr>
<tr>
<td></td>
<td>▪ Navigation error;</td>
</tr>
<tr>
<td></td>
<td>▪ Pilotage error;</td>
</tr>
<tr>
<td></td>
<td>▪ Poor maintenance;</td>
</tr>
<tr>
<td></td>
<td>▪ Falling of a crane;</td>
</tr>
<tr>
<td></td>
<td>▪ Falling of a Container;</td>
</tr>
<tr>
<td></td>
<td>▪ Error in Cargo handling and storage.</td>
</tr>
<tr>
<td>Machinery</td>
<td>▪ Damage to equipment;</td>
</tr>
<tr>
<td></td>
<td>▪ Fire/explosion;</td>
</tr>
<tr>
<td></td>
<td>▪ Machinery failure;</td>
</tr>
<tr>
<td></td>
<td>▪ System failure.</td>
</tr>
<tr>
<td>Environment</td>
<td>▪ Ships emissions;</td>
</tr>
<tr>
<td></td>
<td>▪ Dredging;</td>
</tr>
<tr>
<td></td>
<td>▪ Oil spills, chemical contaminants;</td>
</tr>
<tr>
<td></td>
<td>▪ Ballast waters;</td>
</tr>
<tr>
<td></td>
<td>▪ Ship breaking /salvage activities;</td>
</tr>
<tr>
<td></td>
<td>▪ Air toxics and noise pollution;</td>
</tr>
<tr>
<td></td>
<td>▪ Alien species.</td>
</tr>
<tr>
<td>Security</td>
<td>▪ War / Political instability;</td>
</tr>
<tr>
<td></td>
<td>▪ Terrorist, theft, smuggling;</td>
</tr>
<tr>
<td></td>
<td>▪ Illegal trade;</td>
</tr>
<tr>
<td></td>
<td>▪ Vandalism;</td>
</tr>
<tr>
<td></td>
<td>▪ Illegal immigration;</td>
</tr>
<tr>
<td></td>
<td>▪ Blockade.</td>
</tr>
<tr>
<td>Natural</td>
<td>▪ Earthquakes;</td>
</tr>
<tr>
<td></td>
<td>▪ Volcanic eruptions;</td>
</tr>
<tr>
<td></td>
<td>▪ Hurricane;</td>
</tr>
<tr>
<td></td>
<td>▪ Strong winds;</td>
</tr>
<tr>
<td></td>
<td>▪ Heavy swell and sea;</td>
</tr>
<tr>
<td></td>
<td>▪ Floods;</td>
</tr>
<tr>
<td></td>
<td>▪ High Temperature during working hours;</td>
</tr>
<tr>
<td></td>
<td>▪ Heavy rain.</td>
</tr>
</tbody>
</table>

The Port Risk Assessment (PRA) keeps unchanged the basic number of steps involved in the structure of the Formal Safety Assessment (FSA), modifies it content to better match the seaport use case. Table 2 presents the Port Risk Assessment (PRA) steps.
As in other FSA, risk assessment is often categorized into a qualitative and a quantitative part. Qualitative methods for exploring risk might be influence diagrams, while quantitative methods include fault and event trees and Bayesian networks, where barriers that prevent incidents from occurring or mitigating consequences are typically included.

A typical FSA and Supply Chain approach to risk identification is to list all the plausible risks. The first step typically consists in investigating historical data on previous accidents and or in a brainstorming session, taking into account the limitation of resources.

<table>
<thead>
<tr>
<th>Step</th>
<th>Step Feature</th>
<th>Step Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>System Identification</td>
<td>Port, Container Terminal</td>
</tr>
<tr>
<td>1</td>
<td>Risk Identification</td>
<td>What may go wrong and which port functions/capabilities should be protected</td>
</tr>
<tr>
<td>2</td>
<td>Risk Assessment</td>
<td>Investigation/quantification of most important port risks</td>
</tr>
<tr>
<td>3</td>
<td>Risk Control Options</td>
<td>Measures to mitigate most important port risks and measures to restore port functions/capabilities</td>
</tr>
<tr>
<td>4</td>
<td>Cost/Benefit Assessment</td>
<td>Cost/benefit assessment of port risk control measures</td>
</tr>
<tr>
<td>5</td>
<td>Decision Making</td>
<td>Recommendation and feedback to assessment – Port Risk Index</td>
</tr>
</tbody>
</table>
Risk can be quantitatively and qualitatively assessed with the use of a risk matrix (Table 3) where the rows represent the increasing severity of the consequences of a released risk and the columns represent the increasing probability or frequency of those consequences.

Table 3 - Risk Matrix [12].

<table>
<thead>
<tr>
<th>Frequency (FI)</th>
<th>Severity (SI)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minor</td>
<td>Significant</td>
<td>Severe</td>
<td>Catastrophic</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Frequent</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Reasonable</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Possible</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Remote</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
| 1             | Extremely     | 2 | 3 | 4  | 5  | remote
The matrix shows the combination of likelihood and consequence, distinguishing three regions (as shown in Table 4):

Table 4 - Risk matrix regions [12].

<table>
<thead>
<tr>
<th>Region</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manage for continuous improvement – Acceptable Risk.</td>
<td></td>
</tr>
<tr>
<td>Incorporate risk reduction measures – ALARP – should be reduced until it is no longer economically effective to be reduced.</td>
<td></td>
</tr>
<tr>
<td>Intolerable (Unacceptable) Risk – should be avoided or reduced at any cost.</td>
<td></td>
</tr>
</tbody>
</table>

Risk quantification is calculated by the sum of FI and SI. Table 5 and Table 6 show FI and SI as adapted by the International Maritime Organization (IMO).

Table 5 - Frequency Index (FI) adapted by IMO FSA [12].

<table>
<thead>
<tr>
<th>FI</th>
<th>Frequency</th>
<th>Definition</th>
<th>F (per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Frequent</td>
<td>Likely to occur once per day</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Reasonable Possible</td>
<td>Likely to occur once per month</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Remote</td>
<td>Likely to occur once per year</td>
<td>0.1</td>
</tr>
<tr>
<td>1</td>
<td>Extremely remote</td>
<td>Likely to occur once in a lifetime</td>
<td>0.01</td>
</tr>
</tbody>
</table>

ALARP risks acceptability depends on a cost-benefits analysis.
Table 6 - Severity Index (SI) as adapted by IMO FSA [12].

<table>
<thead>
<tr>
<th>SI</th>
<th>Severity</th>
<th>Effects on Human Safety</th>
<th>Effects on Equipment and Infrastructure</th>
<th>Effects on Environment</th>
<th>S (Equivalent Fatalities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor</td>
<td>Single or minor injuries</td>
<td>Local equipment management</td>
<td>Local environment damage</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>Significant</td>
<td>Multiple or severe injuries</td>
<td>Not severe equipment or infrastructure damage</td>
<td>Non severe local environment damage</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Single fatality or multiple severe injuries</td>
<td>Severe equipment or infrastructure damage</td>
<td>Severe local environment damage</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Catastrophic</td>
<td>Multiple fatalities</td>
<td>Total loss</td>
<td>Catastrophic extended environmental damage</td>
<td>10</td>
</tr>
</tbody>
</table>

In order to prevent aggravation, mitigating measures, emergency readiness, and escalation control measures are required to be in place to stop the spreading events chain and or to mitigate the escalation consequences. Each recovery measure may be associated with one or more failure modes or escalation scenarios.
It is important to propose a cost-effective Risk Control Option (RCO) that comprises the following four main actions:

1. Focusing on the risk areas which need to be controlled;
2. Identifying potential risk control measures;
3. Evaluating the control measures risk mitigation potential;
4. Grouping risk control measures under RCO procedures and regulation options.

The cost-effectiveness of each risk control option (RCO) is evaluated on the basis of its implementation and operation (including maintenance) cost Net Present Value (NPV) over its lifetime ($\Delta C$) and its Risk Reduction ($\Delta R$) over the same period.

Depending on the nature of the risks addressed, the acceptance and prioritization of RCO is weighed against the “Implicit Cost of Averting a Fatality” (ICAF) or the “Cost of Avoiding a Ton of oil Spill” (CATS).

Though there are many suggestions for most appropriate optimal ICAF values, universally accepted values have not currently been established. A specific and recommended RCO belonging to
environmental risk is $\Delta C/\Delta R$. When risks are referred to human and environmental issues and damages, ICAF and CATS $\leq \Delta C/\Delta R$. These criteria refer to the presence of *negative externalities* (namely environmental and human cost). $RCO$ must be improved in order to restore and repair damages in equipment and infrastructure, as well as treating injuries and recover revenue losses. This is the reason why the net effect of private cost ($\Delta C$) and benefits ($\Delta B$) must be also taken into account for $RCO$ prioritization and acceptance.

ICT solutions could be considered as important tools for preventing damages and failures. In this sense, in order to understand how ICT would be an helpful tool to predict harmful events, to prevent efficiency and to avoid revenue streams losses. This is achievable by defining an accurate risk management plan. In this matter, C-Port digital services are described in Chapter 5.
4 Port digitalization: smart ports management and strategic goals

4.1 Industry 4.0 and Ports 4.0

Port logistics is a strategic sector in which there is creation and diffusion of value in terms of optimization of logistics processes and in terms of environment and collective well-being.

Therefore, anticipating the demand without being caught unprepared by disrupting innovation is essential. Erroneously, ports are historically considered static realities, with little inclination to change and whose activities are considered accessory and without added value. Information Technology is the main character of the digitalization era, everything is connected in a “smart” way, businesses and their industrial processes have been reengineered according to the so called “4.0” paradigm. Ports have been involved in this kind of disrupting innovation too.

According to the technology setting, “smartness” usually refers to the principles of automatic computing, however, a globally accepted definition of “smart port” does not already exist, it has not been well
defined in the literature, as well as an internationally accepted and standard definition for the word “smart” does not exist in the context of port industries and maritime scenario [13].

Transforming a “traditional” port into a “smart” port is not a mere demonstration of virtuosity, but rather it represents a true technological challenge in terms of increasing productivity, resource optimization and environmental and energy safeguarding. In this respect, it is also true that significant investment in digital infrastructure is required. Introducing a new technology, such as an ICT standard platform, requires a decision making methodology, as the investment in ICT digital infrastructures must meet the ad-hoc decision making criteria, defined to justify the technology investment selection procedure. It is therefore essential to understand what are the alternative solutions costs and benefits, in order to select the one most appropriate to the case.

From an economic assessment point of view, digitalized ports can achieve important “impacts”, or effects: first of all, in terms of microeconomic effects, since we have an increase in overall surplus
welfare) and, according to long-term growth, through the achievement of economies of scale and increased production specialization. According to the *New Economic Geography Models* (Krugman, 1991), infrastructural upgrading can lead a company located in a specific area to have access to a wider market, as a result of lower transport costs. At the same time, other producers are encouraged to operate in that area, feeding an increasingly attractive spatial concentration process and increasing the local market competitiveness [14].

In terms of macroeconomic effects, the Return on Investments in port infrastructure is expected to arise, as well as the long term GDP. This is a consequence of the high seaport infrastructures elasticity of GDP, which suggests that seaports infrastructures have an important indirect effect on economic growth. In order to boost seaports quality of services and efficiency, any national economy, consider seaports as crucial business systems operating in a high competitive market, which require continuous development and specific infrastructures improvement and investments [15].
Moreover, port sector plays a fundamental role in the national economy, as it provides job opportunities for millions of people.

When introducing a new technology (like 5G connectivity) a decision making process, based on the cost-benefit analysis, must be followed. Innovation costs, benefits are not immediate, they will emerge in the next years, as technology equipment represent an investment in durable goods. Firstly, organization have to check why the port should invest in innovation. Simulations are useful to assess the magnitude of benefits coming from the technology investment and an impact analysis must be provided to develop ad-hoc port investment planning.
4.2 The technology transfer

There is no single definition for the concept of "technology transfer", it must be analysed from a wider point of view. The "Treccani" encyclopaedia offers the following definition: "The set of activities carried out by research centres aimed at the assessing, protection, marketing and commercialization of technologies and, more generally, at the management of intellectual property developed within the framework of research and development projects conducted by the academic world" [16].

The activities linked to technology transfer can be defined as "those initiatives designed to economically promote the results of research which, typically, are developed through the acquisition of patents and their subsequent extension to businesses". We can therefore say that the concept is closely linked to the definition of "commercial exploitation" of the resource or project.
The technology transfer process consists of four macro-phases:

1. Identification and industrial application of new technologies;
2. New technologies protection, through patents, trademarks, copyrights and projects registration;
3. Ad-hoc marketing strategy definition and implementation;
4. Technology transferring, through the exploitation licenses selling and purchasing to existing companies or through the creation of new companies.

The valorisation, and consequentially the transfer, of scientific and technological results from research centres, hold a crucial and increasingly relevant role in terms of economic development. Indeed, it is considered the driver for the transition from a “manufacturing-based economy” to a "knowledge-based economy".

Scientific hubs play a dominant role in the economic development process, becoming active partners in supporting the industrial system competitiveness. In this sense, universities and research centres feel the need to expand their typical "mission" of creating and
disseminating knowledge toward ad-hoc collaboration with productive realities having the purpose of improving economic and social welfare. Hence, universities and public research centres need to make a special organizational and procedural effort.

4.3 Focus: Livorno as Port of the Future

Adopting private 5G cellular technology in the port area will boost productivity and turn it into Ports 4.0.

One of the biggest challenges for port development is how to evolve and to be competitive, more efficient and sustainable. Thanks to 5G technology, Ports of the Future also produce economic benefits resulting from reduced operating costs, lower fuel consumption and weaken crane and forklift effort, with a shorter ship-cycle.

The port of the future will need to use always-connected sensors and enhanced applications that control and make decisions in real-time, to provide intelligent insights into the port’s condition and operations [17]. With the aim of allowing a transparent and efficient communication among the port stakeholders, smart ports are
expected to seek the digitalization of freight documentation, the use of standardized communication technologies in the daily port operations, as well as the massive use of ad hoc wireless communication technologies [18].

We have a common vision for 2030 Ports, as they will be capable, efficient, sustainable and highly connected with the inland logistics networks and corridors. Following the European models, they will be compliant to the circular economy paradigm and port environmental footprint will be significantly reduced, as well as noise and air pollution impact. Port channels and basins navigability will be improved, as well as logistics flows and operational efficiency.

Thanks to 5G connectivity and automation, port operational capacity will be extended, until to achieve a 24/7 availability. This will not led to a staff cut, but to a labour digital skills specialization.

Technology impacts on society will be positive and challenging, especially regarding four main bundles [19]:
1. *Running a tighter ship* – assets development for managing giant vessels;

2. *Unlocking the gridlock* – cutting yard congestion;

3. *People-friendly ports* – automation elements that keep workers safe;

4. *Getting greener by getting smarter* – as a result of improved yard movements.

In order to let several Ports of the Future interoperable, standards represent key necessities. Information and communication protocols need to be standardized in order to create trusted environments and to encourage innovation actions\(^7\). From an economic point of view, standardization is a market expansion booster, because it lowers production costs and increases market competition.

\(^7\) How Standard C-Port services have been developed is described in Chapter 5.
4.3.1 *The AdSP-CNIT Joint-Lab*

On October 2015, the Port Authority of the Northern Tyrrhenian Sea (*AdSP*) has signed an agreement with the Interuniversity Consortium for Telecommunications in order to create a research and innovation hub.\(^8\)

The *AdSP-CNIT Joint Laboratory*\(^9\) is a protagonist of innovation, as a multipurpose platform that, through enabling technologies, can generate significant system effects in a well-defined vertical sector, characterized by private and institutional stakeholders.

According to the analysis carried out by the *Tuscany Region* and *SVC Consulting* for the Tuscan platform "*Industry 4.0*" [20], the Livorno technology hub represents one of the six laboratories, also known as "*knowledge production hubs*", located outside the Tuscan technological districts. Knowledge production hubs are attractive poles of innovative industries, research and skilled employment, in fact, such

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\(^8\) The agreement full text is available on AdSP website (link).

\(^9\) Joint Lab website is available at: https://jlab-ports.cnit.it/.
districts characterized from aspects of geographic ad peripherical marginality, hold greater services of technological specialty. The potential of those centres for the innovation, not favoured by a centrality position, results therefore particularly remarkable.

The AdSP-CNIT hub provide an important contribution to the creation of "inter-industry spill-over" (upstream and downstream, through the supply chain), and "intra-industry spill-over" (in different sectors). The term "spill-over" refers to “a set of positive externalities generated by organizations that, by investing in a certain activity, cannot prevent other parties from appropriating the benefits of their actions (even without necessarily having to enter into negotiations with them)”. A company which benefits from the "spill-over" has not directly sustained the costs for its generation (although, it sustains an inevitable absorption cost). The spill-over effects are greatly accelerated in the presence of large firms and-or in the presence of a upstream and downstream local firms chain. Actually, knowledge is not an asset that can be fully appropriated or excluded and should not be considered a productive factor in the strict sense.
In a very short summary, the "spill-overs" generated by the joint laboratory can be summarized as follows:

1. The lab supports the Port Authority in playing a stronger role at the strategic planning level for the territory;
2. The port’s digitization project enables great efficiency improvements through cost savings;
3. The contribution to the training of new professionals (contribution to the creation of degree courses and university masters for the training of new professionals);
4. *MoniCA* standard platform\(^\text{10}\) is a solution that can be "exported" to other ports;

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\(^{10}\) *MoniCA* (https://www.monicapmslivorno.eu/) is the *AdSP* monitoring and control platform, which collects and integrates heterogeneous data coming from a multitude of IT sources, such as applications or distributed sensors. *MoniCA* services are organized in specific functional areas and designed for a public and private plurality of users.
5. Currently, the Laboratory is able to attract public resources by ensuring activities for about twenty people and progressively raising the quality of ICT technology;

6. In perspective, innovative services should guarantee the actual level, or even increase, port competitiveness.

The CNIT-AdSP joint laboratory (JLAB) represents the link that will allow the Port of Livorno to explore and to manage ICT service platforms to enable a continuous evolution of port and logistics processes, connected to the opportunities of innovation.

The innovation hub is jointly managed by AdSP and CNIT: while in Europe similar figures are configured as “autonomous entities”, Livorno has opted for the creation of an "internal innovation unit". The AdSP-CNIT joint laboratory is a “peer-to-peer” relationship enabler providing high-level skills, academia and business networks for European design and collaboration in industrial innovation processes, with the availability of a testbed, real industrial requirements, possibility of replication in other European ports.
The objective of the JLAB are the following:

- To collect the requirements from the communities and design innovation services;
- To follow (and steer) EU standardization for data, networks and services;
- To allow the procurement from the digital market of innovation services;
- To check the conformance against the requirements (included in tenders).

On the basis of the AdSP and CNIT agreement, the two partners jointly provide resources to the laboratory, and an annual work plan is defined and approved. In the eyes of other organizations, due to the "hybrid" nature of the joint laboratory, it is not easy to define the role of the innovation hub, especially with regard to its potential to promote local development.
A possible shift from an innovation hub into an autonomous company could help to ensure greater clarity towards stakeholders inside and outside the port system.

For the laboratory work a total of eighteen qualified people, about ten of them are researchers and IT experts, the others are experts in logistics, economics and port management. This particular mix of competences represents, in fact, a unicum.

The common vision that binds AdSP and CNIT is that the port of Livorno should be configured as an asset capable of "enabling" innovation. Starting from the port digital platforms, it is possible to activate innovation processes and services that will create benefits for the Port Community and local communities.

An example is related to maritime traffic optimization, "autonomous and connected ships" increase the ship movements sustainability and safety. Again, considering also the territory in which the port is located in, smart mobility and info-mobility apps, C-ITS tools for
traffic control, smart sensors for and acoustic and air quality control and blockchain integrated services are enabling tools.

The current challenge is not just to computerize what we have, but to reorganize all processes in a "digital logic", with the aim of promoting the competitiveness and responsiveness of the logistics system and its whole connection to the reference production chains.

Regarding the financial aspects, in the five-year period 2013-2018, the ports of Livorno and Piombino have obtained a total of 5.8 million euros of European funding.

Participation in European programs has allowed them to be part of qualified institutional and scientific partnerships that are crucial for the strategic positioning of the ports at national and international level. Four projects have been financed under the "Horizon2020" research program and in particular two of them under the "Port of the future" call. Other projects are part of the "Interreg" program for cross-border cooperation.
The port system of Livorno is one of the main European players operating in synergy with ERTICO, ALICE, ETSI, ESPO and so on. In addition to the contributions granted by the projects, the Port Authority funds agreed in the convention are provided: an annual contribution of euro 80,000 of direct funding to cover operating expenses, as well as contributions to support AdSP and CNIT in terms of personnel and instrumental and technological resources.
5 The C-Port services

5.1 EU guidelines for C-Ports

The strategy followed in the European Union for the adoption of C-Roads in large-scale deployment is also applicable to the seaport sector. Hence, it is possible to talk about “C-Ports” [21].

A deep standardization activity in the C-ITS domain has in fact permitted to open the business of Connected and Autonomous Vehicles to the Digital Single Market, as all the main roads in Europe adopt the same standards, offering a basic set of services (e.g. alerts to road works, in-vehicle signage etc.) to the high-tech vehicles manufacturers, as to let vehicles communicate and interact with each other and with the "smart road".

The main C-ITS platform result is the final user services classification into nine bundles (i.e., safety, vulnerable road users, urban, motorway, parking, smart routing, freight, collision, wrong way). According to the service Technical Readiness Level (TRL), each service
is labeled as “Day 1”, “Day 1.5” or “Day 2” (a more detailed description is provided in the “C-ITS platform phase II final report” [22]).

The European Commission, as well as the single EU Member States, have sponsored many innovation projects in order to support several business-oriented initiatives with two main objectives:

- To meet the emerging development trends in the target "verticals" (as Mobility, Logistics, Port Community, Transportation Systems and so on);
- To develop Key Enabling Technologies (as Mobile Networks and IoT, Digital Platforms and Cloud Computing, Blockchains, Artificial Intelligence, etc.).

Ports can be also subjected to this kind of “disrupting technologies” (like C-Roads) in order to implement the standards by the international Standard Setting Organizations (such as IMO, ISO, ETSI UNECE) for homogenous information flow, Electronic Data Interchange (EDI) and logistics procedures. Mainly, EU Directives regulate the arrival or departure set of information (ships schedules and forecasting),
passengers and freight customs controls, dangerous freight (and/or waste and residuals) notification system, security to entry ports and declaration summary related to customs clearance.

All directives aim at implementing electronic information exchange systems, in order to avoid untrusted and duplicated data and letting member states (both EU and IMO) to set up a Single Point Of Contact (SPOC) accessible through a National Single Window (NSW). The idea is to abandon the existing “silo” legacy information systems, managed by the single organizations by adopting a standard and fully-interoperable solution. While this approach is opening a genuine competition among European ports, the absence of a comprehensive standardization force roaming users (i.e. Vessels, Trucks, Trains, and their personnel) to adapt to multiple port service configurations or rely on local specialists for full-customized solutions. This leads to an increase in operating costs.
5.2 Research and development fields

It has been decided to classify port digital verticals into bundles, according to the C-Ports paradigm, which aim at offering modular and "tailor-made" solutions for the digitalization of port processes. C-Ports services will belong to three verticals and one horizontal, described in Table 7.

Table 7 - C-Port services R&D fields [21].

<table>
<thead>
<tr>
<th>R&amp;D field</th>
<th>Type</th>
<th>Regulator</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel and Marine navigation</td>
<td>Vertical</td>
<td>ISO and IMO (mainly)</td>
<td>• Vessel Traffic Management;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Vessel maneuvering in port waters;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Accident at Sea;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Suspicious Vessel / Maneuver;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Berth allocation and docking.</td>
</tr>
<tr>
<td>E-freight and intermodal logistics</td>
<td>Vertical</td>
<td>UN/EDIFACT and not-standard proprietary solutions</td>
<td>• Freight Management and Control;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Gate Automation;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• In-port Smart Navigation;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Freight Routing;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Accident at Landside.</td>
</tr>
<tr>
<td>Passenger transport</td>
<td>Vertical</td>
<td>ISO, IEEE, MaaS Alliance(^{11})</td>
<td>• Infomobility and journey monitor;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Integration with TCC;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• In-port Smart and Autonomous Mobility (including safety).</td>
</tr>
<tr>
<td>Environmental control</td>
<td>Horizontal</td>
<td>UN protocols</td>
<td>• Pollution Level (including COx and noise) reduction;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Road Traffic Level monitoring and control;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Dynamic pricing (all services) to Vessels, Terminals.</td>
</tr>
</tbody>
</table>

\(^{11}\) Mobility as a Service applications are standardized by MaaS alliance. More information available at https://maas-alliance.eu/.
Services and product requirements are defined by the needs of the specific user-personas\textsuperscript{12}, representing port stakeholders. Figure 3 shows a graphic representation of C-Port user personas and R&D areas.

\textit{Figure 3 - Research and development areas and user-personas.}

\textsuperscript{12} The user-personas are introduced and described in Section 2.2.3, which illustrates port communities.
Table 8 describes who are the user-personas involved in every specific vertical or horizontal.

Table 8 - User-personas and research and development fields.

| Vessel and marine navigation                                      | - Ship captain;                              |
|                                                                  | - Ship owner;                                |
|                                                                  | - Shipping company controller;               |
|                                                                  | - Terminal operator;                         |
|                                                                  | - Municipality administrator;                |
|                                                                  | - Regional administrator;                   |
|                                                                  | - Port maneuvering crew.                    |
| E-freight and intermodal logistics                                | - Local SME entrepreneur;                    |
|                                                                  | - Shipping company controller;              |
|                                                                  | - Railway operations planner;                |
|                                                                  | - Freight forwarder;                        |
|                                                                  | - Custom operator;                          |
|                                                                  | - Truck driver;                             |
|                                                                  | - Terminal operator.                        |
| Passenger transport                                               | - Tourism operator;                         |
|                                                                  | - Regional administrator;                   |
|                                                                  | - Public transport manager;                 |
|                                                                  | - Tourist;                                  |
|                                                                  | - Municipality administrator;               |
|                                                                  | - Commuter.                                 |
| Environmental control                                             | - Shipping company controller;              |
|                                                                  | - Regional administrator;                   |
|                                                                  | - Municipality administrator;               |
|                                                                  | - Entrepreneur;                             |
|                                                                  | - Terminal manager;                         |
|                                                                  | - Citizen                                   |

Thus, it is important to analyze the expectations and user needs, to make them part of the process of development, by collecting feedback, deriving from their experience, with a continuous improvement approach. The level of involvement of the port communities can in fact be assessed through the definition of "ad-hoc" Key Performance
Indicators (KPIs), as these indicators can provide important information about the validity of models and prototypes.

5.3 Road to standardization and interoperability

According to the C-Port paradigm, every smart port offers tailor-made services to its port community. This is achievable by using standard data interchange protocols and standard digital platforms, in order to let the systems interoperate with each other.

5.3.1 Day 1, day 1.5, day 2 services

C-Port services enable new digital functions to the port community, which can be considered as an active partner of the 24/7 smart port value chain [21].

In this sense, the port community stakeholders and partners can benefit of the port digital environment (as shown in Table A 1 and Table A 2 in the Appendix). The prospected final user applications are then labeled as Day 1, Day 1.5, and Day 2 services in consideration of
the technical and commercial gaps to be filled (depending on their technical readiness).

We will refer to Day 1 services when they are already considered in standardization and can be achieved by state-of-the-art technologies; we will refer to Day 1.5 when they have not yet been proposed in standardization and need to address challenges in technologies; we will refer as Day 2 for services, still beyond state-of-the-art, not yet considered by Standard Setting Organizations and technologically.

5.4 C-Port commercial exploitation

C-Port services must follow a commercial exploitation plan, in order to extend the smart port concept to the other logistics hubs, which are part of the maritime network.

In this sense, a feasibility study must be investigated, with the purpose to understand the services time-to-market depending on the specific business case.
User requirements must be defined, in this sense a strategic partnership with the major ICT players is needed. Users adoption rate must be investigated, as well as the compliance to the standards and law requirements.

Most specifically, according to the SWOT Analysis paradigm, the factors to keep in mind are both external and external, as there are several factors which can may have a positive or negative influence on the business strategy.

SWOT Analysis is a globally accepted framework for evaluating organizations according to their strengths, weaknesses, opportunities, and threats. It is helpful for understand what an organization can do, what is lacking or missing, to minimize risks, and to understand the possible chances for success. Commercial exploitation strategy is shown in Table 9.
Table 9 - SWOT analysis.

<table>
<thead>
<tr>
<th>Strengths (internal)</th>
<th>Weaknesses (internal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Being a reference in the market;                                                   ▪ Heavy future updates may be needed;</td>
<td></td>
</tr>
<tr>
<td>▪ Strategic position as logistics hub;                                                ▪ High development cost;</td>
<td></td>
</tr>
<tr>
<td>▪ Real time navigation, e-freight and passenger management;                         ▪ Poor willingness to change;</td>
<td></td>
</tr>
<tr>
<td>▪ Demand-driven development;                                                         ▪ Applications heterogeneity</td>
<td></td>
</tr>
<tr>
<td>▪ Open data paradigm</td>
<td></td>
</tr>
<tr>
<td>▪ Safety, decarbonization, environmental control;</td>
<td></td>
</tr>
<tr>
<td>▪ Data come from heterogeneous data sources;</td>
<td></td>
</tr>
<tr>
<td>▪ High-skilled team;</td>
<td></td>
</tr>
<tr>
<td>▪ Compliance with the standards;</td>
<td></td>
</tr>
<tr>
<td>▪ Possibility of absorption of EU funds for development;</td>
<td></td>
</tr>
<tr>
<td>▪ Port area as a test-bed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunities (external)</td>
<td>Threats (external)</td>
</tr>
<tr>
<td>▪ ICT and logistics represent promising sectors;                                     ▪ Risk of cybersecurity attacks;</td>
<td></td>
</tr>
<tr>
<td>▪ Partnership with market leaders;                                                   ▪ Political/institutional environment;</td>
<td></td>
</tr>
<tr>
<td>▪ Technology maturity;                                                               ▪ Requirements and procedures may change</td>
<td></td>
</tr>
<tr>
<td>▪ New job opportunities;                                                             ▪ Poor integration with the other supply chain actors</td>
<td></td>
</tr>
<tr>
<td>▪ Port-city relationship;                                                            ▪ Strong competition from other ports and business in the hinterland</td>
<td></td>
</tr>
<tr>
<td>▪ High investment in digital infrastructures</td>
<td></td>
</tr>
</tbody>
</table>

13 Traditionally, supply chain actors do not use innovative systems.
While developing the new C-Port features, the innovation lab has taken into account the most competitive and innovative business in the ICT and logistics sector, as well as telcos, insurance companies and shipping company. Outcomes are expected in the next three years.

Due to the port sector characteristics, exploitation activities can take place while participating to international summits, like the Barcelona “Smart City Expo”, where the most innovative entities can meet.

According to the EU Commission guidelines, ports are turning into innovative industrial district, with the aim to include private businesses into the value creation process. This kind of innovation opens the market to new important business opportunities and partnerships.
6 The C-Port vector

6.1 Smart Port Indexes: State of the Art and critical issues

According to the technology setting, “smartness” usually refers to the principles of automatic computing, however, a globally accepted definition of “smart port” does not already exist, it has not been well defined in the literature, as well as an internationally accepted and standard definition for the word “smart” does not exist in the context of port industries and maritime scenarios. Houston University has defined a Smart Port Index (SPI) to measure ports “smartness” [13].

Nevertheless, the different entities may not be easily comparable due to their service and structural heterogeneity, which complicates ports scoring and ranking process.

Also, many KPIs referenced in literature are subjective and cannot be compared from port to port such easily; it is therefore worth to consider an indicator calculated from C-Port services only [21].

When the C-Port services are standardized, it will be possible to rank all ports on the basis of an indicator having gathered consensus. It will
also be possible to profile each port on the basis of its genuine offer without generating artificial outperformances.

Differently from Houston University Researches [13] we decided to decouple “Operations” related to logistics from those related to mobility to match the port specificity along one or the other axis and to consider “Energy” as one of the aspects related to Environmental Sustainability.

These considerations pave the way towards the definition of the C-Port Vector.
6.2 C-Port vector: mathematical formulation

As a unique comprehensive metric is welcome to rank ports for their ICT innovation potential, the following C-Port Vector whose i-th component is proposed:

\[
\text{C-PV}_i = \rho |\mathbf{a}_i \mathbf{C}_{ij} \times |\mathbf{w}_j| = \rho \cdot \begin{pmatrix}
    a_{Nv}P_{Nv} & a_{Nv}D_{Nv} & a_{Nv}R_{Nv} \\
    a_{Fr}P_{Fr} & a_{Fr}P_{Fr} & a_{Fr}R_{Fr} \\
    a_{Mb}P_{Mb} & a_{Mb}P_{Mb} & a_{Mb}R_{Mb} \\
    a_{St}P_{St} & a_{St}P_{St} & a_{St}R_{St}
\end{pmatrix} \cdot \begin{pmatrix}
    w_P \\
    w_D \\
    w_R
\end{pmatrix}
\]

\[(i = \text{Nv, Fr, Mb, St})\]

*Equation 1 [21].*

- \(\rho\) is defined as the *standardization merit factor*, calculated as the ratio of adopted standards on the applicable standards;
- \(\mathbf{C}_{ij}\) is the *port innovation matrix* where the element represents the total cumulative cost in unit of M€ of project work expenses for developing new Prototypes (TRL \(\leq 5\)), new Demos (6 \(\leq\) TRL < 8), and new Released applications (TRL \(\geq 8\)) in the four C-Port application areas (Navigation – Nv, Freight – Fr, Mobility – Mb, Sustainability – St);
The $|a_i|$ vector represents the port specific businesses (either freight, or passengers, or energy) where the navigability is considered higher for stormy or narrow ports than in accessible ones.

A normalization constraint applies as $\sum \frac{1}{a_i^2} = 1$;

- the $|w_i|$ vector represents the innovation reward, i.e., the weight assigned to early development of innovative technologies in respect to mature deployments.

A normalization constraint applies as $\sum \frac{1}{w_i^2} = 1$;

If detailed records about innovation projects are not available, it is always possible to quote the total investment summing all elements in the port innovation matrix:

$$\text{Tr}(\mathbf{C}^\top \mathbf{C}) = \sum_i \sum_j a_{ij}^2$$

*Equation 2 [21].*

where $\mathbf{C} = [\sqrt{a_{ij}}]$ is introduced to get rid of the quadratic summation.
6.2.1 Properties of the C-Port Vector

The metric defined in Equation 1 shows the following properties that render it robust and eligible for global usage:

1. The C-Port Vector is null if no standard is adopted. Two ports with similar innovation potential can result into C-Port Vectors with very different modules if one of them relies on proprietary solutions;

2. Projects are weighted in terms of their cost as it is hard to consider other performance indicators (like publications, number of new tenure positions, etc.) without generating any systematics;

3. Different ports have different C-Port Vectors in the 4-dimension space so that it is possible to define the scalar product of C-Port Vectors representing the port vocation (as freight, passengers, energy, etc.), as well as to compare the effort devoted to innovation along the 4-axes.
The generic angle between two C-Port vectors is defined as:

$$\alpha = \cos^{-1}\left( \frac{C-PV_1 \ast C-PV_2}{|C-PV_1| \cdot |C-PV_2|} \right)$$

Equation 3 [21].

Of course, the two vectors can represent two snapshots of the same port taken in different timing. This will be investigated as Case Study in Paragraph 6.2.2.

4. the innovation reward is a tunable parameter that can privilege ports connected to innovation realms (like research campuses and universities, start-up’s, etc.) featuring early-stage digital services or those having already released new services to the user communities.
6.2.2 Dynamics of the C-Port Vector in Livorno

The C-Port vectors for the port of Livorno have been calculated by considering the Port Authority investments in innovation (reported in Table 10) during two biennia [23]. Respectively C-PV₁ refers to 2017-2018 and C-PV₂ refers to 2019-2020.

<table>
<thead>
<tr>
<th></th>
<th>Vessel and marine navigation</th>
<th>e-Freight &amp; intermodal logistics</th>
<th>Passenger transport</th>
<th>Environmental sustainability</th>
<th>TOTAL AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>137 k€</td>
<td>773 k€</td>
<td>82 k€</td>
<td>310 k€</td>
<td>1,304 k€</td>
</tr>
<tr>
<td>2018</td>
<td>269 k€</td>
<td>435 k€</td>
<td>770 k€</td>
<td>3,447 k€</td>
<td>4,922 k€</td>
</tr>
<tr>
<td>2019</td>
<td>444 k€</td>
<td>-</td>
<td>-</td>
<td>492 k€</td>
<td>937 k€</td>
</tr>
<tr>
<td>2020</td>
<td>-</td>
<td>71 k€</td>
<td>-</td>
<td>80 k€</td>
<td>151 k€</td>
</tr>
</tbody>
</table>

As the same attention has been devoted to require the compliance to the standards, where available, we consider \( \rho \) (as defined in Par. 6.2) constant in the two biennia.

The \( \alpha \) angle between the two C-Port Vectors, calculated from the definition of the scalar product in \( \mathbb{R}^4 \) (see Equation 3), is equal to 35°.

This is not surprising, as the innovation agenda has deeply changed
from 2017 to 2020 [24], where more applications have been submitted in the vertical sector of vessel navigation.

Pictorially we render the dynamics of the C-Port Vector as it follows:

![Diagram](image)

*Figure 4 - Dynamics of the innovation at the Port of Livorno estimated from the evolution in time of the C-Port Vector [21].*

*Table 11 - Individual bundles as a percentage of investments [21].*

<table>
<thead>
<tr>
<th></th>
<th>Vessel and marine navigation</th>
<th>e-Freight &amp; intermodal logistics</th>
<th>Passenger transport</th>
<th>Environmental sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 - 2018</td>
<td>0,01</td>
<td>0,09</td>
<td>0,04</td>
<td>0,86</td>
</tr>
<tr>
<td>2019 - 2020</td>
<td>0,37</td>
<td>0,01</td>
<td>-</td>
<td>0,62</td>
</tr>
</tbody>
</table>

14 The $\alpha$ angle would have been null in case of continuity, or very different from zero in case of sensible changes in the innovation agenda [21].
Table 11 shows the weight of each bundle (component) on the total investment. It is noted that Livorno is an ancient port (founded in the XVI Century) with many navigability limitations in adverse meteorological conditions. This is pushing the administration to invest in navigation and maneuvering machine-aided systems to improve the 24/7 accessibility of the maritime node.
7 “5G smart port”

7.1 Industry 4.0 and 5G private networks

ICT technologies could be used to define and implement a smart port. In a “everything as a service” (XaaS) paradigm, 5G connectivity acts as the “glue” that sticks the puzzle together. Rather than being used for personal purposes, 5G networks are a powerful tool for realizing the Industry 4.0 concept because of their achievable high performance.

The introduction of 5G in the industrial market will be fundamental to fill digital transformation gap of the Italian companies, since 5G features will be able to act as facilitator and thus lead to the complete innovation of production infrastructures and business processes. For this purpose, the first and essential step will be the integration of the new communication standard in the companies’ ICT infrastructures.

From the architecture and technology point of view, we can identify two methods: the set-up of private 5G networks and the definition of 5G Network Slices for specific industrial sectors.
5G technology does not only allow to reach a data transmission speed up to 10 times higher than the one ensured by the actual 4G networks, but also to manage at the same time millions of connected entities necessary for the development of Industry 4.0 applications, and to achieve very low latency and high reliability connections which are necessary for real-time control and monitoring in business processes.

Companies anticipate cross-industry use of 5G, with applications covering critical verticals including industrial robotics, connected logistics, the use of drones and autonomous vehicles, augmented reality, and immersive entertainment, physical and cyber security, healthcare, and the evolution of marketing and sales techniques.

The paradigm is similar to that of LTE private networks, in fact a private 5G network provides a campus or a manufacturing area wireless coverage through the "on site" dedicated 5G antennas deployment.

Such a deployed network can offer unified connectivity, a full available optimized access to business applications (from personnel
and industrial automation systems) and, at the same time, a secure communication mean inside the covered area, thanks to the local processing of sensitive or business critical data. This ensures high efficiency levels at a functional and operational scale, also containing network development and operational costs.

At the moment, the most promising scenario for 5G private networks in Italy foresees the deployment of Small Cells in the 26 GHz band. In this case, Telcos can sell these solutions to companies in "as a Service” regime, or else autonomously, businesses develop their own private networks. Even though in Italy the 26 GHz spectrum is licensed to Telcos, it can be granted on a local basis in "wholesale" mode to vertical players that intend to independently manage their own coverage.

Following the 5G rollout in the smart industry, it will be possible to set-up Network Slices dedicated to specific business sectors. By means of the Slices, Telcos will be able to offer subscriptions to their customers in the Enterprise market. The programmability nature of the Network Slicing paradigm will enable Network Slice as a Service (NSaaS) business models.
Telcos are not limited to the role of simple connectivity providers, but they will have the opportunity to develop a full-scale value chain proposal. When developing such propositions, operators will also need to leverage assets, skills and know-how that are not traditionally available in a Telco. These resources will be essential for a complete Enterprise business proposition.

Strategic partnerships and consortia aimed at covering the various segments of the 5G Enterprise market are already international trends, and Telcos on one hand will have to re-engineer and innovate their services, and on the other hand will define system partnerships that allow to integrate the capabilities that are necessary to achieve a complete end-to-end proposal [25].
7.2 5G in port areas

Ports are large-scale industrial deployments handling 90% of global cargo traffic. However, many ports are still having issues in integrating and fully optimizing automation systems into their processes in order to reduce operational delays caused by vessel and truck congestion at the occurrence of unforeseen events (such as the recent blockage of the Ever Giver vessel in the Suez Canal). This applies to port cities as well, where these ecosystems are more instable and a higher degree of co-governance is required [26].

For instance, by knowing in advance the arrival time of a ship carrying trackable freight, it is possible to well arrange the transhipment operation without a stock-break, by avoiding queues and delays at the port gates or at sea. Moreover, vehicle arrivals can be scheduled in a specific and precise way, as not to congest port and city areas. This is ideally achievable by integrating traffic data in the routing algorithm, which is helpful for planning alternative routes in case of traffic jams.

Full digitalization of the logistics chain with the deployment of smart, safe and secure "fast corridors" (interconnecting logistics nodes like
rail-road terminals usually located in the city outskirts) will address the usual target of logistics, namely that of time and cost savings while reducing the pressure towards the city and its daily life. 5G networks can indeed let smart ports address real-time challenges [26], with a cost overhead reduction of 2.5 M€ [17].

5G speed and low latency can enable different use cases boosting the aforementioned ones. Artificial Intelligence is crucial for improving forecasting in port operations. Having the ability to anticipate demand for berthing and other services simplifies operations and improves customer experience. Connecting so many devices (such as, for example, HD cameras) over a large area is typically very expensive, 5G can connect them with no need to implement any additional communications infrastructure.

Ports have been aspiring to remotely and autonomously control and handle equipment (such as forklifts and cranes) for some time. The 5G network in the port can also be exploited to enhance safety, such as to detect faults in high-voltage cables across the site by leveraging highly secure transmission of diagnostic data through artificial intelligence-
based quality control systems hosted in the cloud. As a result, it increases safety for all port employees.

Testing new 5G solutions for real-time management of cargo and port operations is also important for defining new decision-making strategies. In order to make this possible, smart ports are becoming data technology hubs that will help to revolutionize global transportation and logistics systems.

5G networks aim at improving port attractiveness and competitiveness on a national and international scale. In fact, operators will be able to develop new use cases based on real-time data, also thanks to tools (such as connected robotics) that enable maintenance operations, including preventive ones, through augmented reality systems and remote assistance.

New perspectives are opening up for port of the future use cases, such as remote-controlled cranes for moving goods from ship to shore, automated vehicles for moving goods, condition-based monitoring, predictive maintenance and drones.
Ports are becoming data hubs, enabling the monitoring of people, processes to assets throughout the supply chain. Real-time data collection and analysis will help ports create new use cases that consider customer experience. 5G networks will enable data collection and generation. This will offer ports visibility and predictability while supporting their evolution [26].

7.2.1 The digital ship-cycle

Figure 5 shows the ship-cycle in the port area.

1. Ships must obtain a specific Coast Guard authorization to enter the port area, then we have the so-called “ship call”. This kind of authorization come from the Italian AIS system (PMIS);
2. Then, the vessel enters port waters (Figure 5 “green area”);

3. Subsequently, the vessel starts the maneuvering and berthing operation, piloting services are implemented atop, on MoniCA standard platform;

4. Then, goods are unloaded from the vessel and placed in a designated area in the terminal stocking yard. Goods must correspond to the record included in the shipping documents. The information systems involved in these operations are PCS and “Custom Agencies Integrated Automation and Excise System” (AIDA). Terminal have their specific Terminal Operation System (TOS) to manage freight. The vessel at berth is refueled and unloaded from freight;

5. Terminals manage cargo stocked in their stocking yard using computerized aided systems (TOS, PCS);

6. Thereafter, cargo is loaded on the vessel, which is ready to depart. Again, goods must correspond to the shipping documents. Custom clearance authorization is needed;
7. Lastly, the vessel is ready to leave the port area, but only after authorization from the Coast Guard. Departure time is annotated into the PMIS (Maritime NSW).

7.2.2 5G smart docks

Historical ports can evolve and adapt to become smart and sustainable environments, however ICT technologies, in particular 5G networks, can enable a new “24/7 port” paradigm, based on the full port area and hinterland integration. This system will lead to a process improvement and to emissions and cost savings.

When developing new technologies within real scenarios, Port Authorities and other organizations need to tailor their impact on the overall processes and performances in terms of sustainability, competitiveness and prospects of success.

Talking about sustainability, a recent study run by the Italian Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) shows that twenty-one Italian ports may be affected by
climate change disruptive actions (like the global sea level rising) because they do not respond appropriately to the environmental issues [27]. With respect to emissions, ports must be compliant with the requirements stated in the *Paris Climate Agreements* and the scientific recommendations. In this sense, it is known that ICT can reduce greenhouse gas emissions by 15% in almost all the worldwide economic and production sectors, even regarding mobility, logistics and supply chain. Ports must deal with particular monitoring and control tools in order to analyze and mitigate the environmental impact of all the possible pollution sources, making also use of ad-hoc cooperation with specific partners. Climate changes and sustainability is a crucial socio-economic factor that also has implications on the occupation level, the local, national and international economy. It follows that new business models, capable of value and wealth improvement also via a strong collaboration with key partners and stakeholders, are emerging.

Environmental changes challenges are not the only reason for moving to a 5G smart port. According to secure process optimization and cost
savings, the new 5G cellular communication technology can support the 4.0 approach in ports logistics, because this new connectivity can meet a new range of specific efficiency requirements concerning, in particular: automation in the port area (even benefiting of an enhanced human-devices coordination), real-time massive data collection ad analytics, smart system optimization. The port of the future (as described in section 4.3) is fully connected and sensorized, so it needs specific technology and connectivity requirements in order to keep all the smart port specific application working. It is well known that a fixed “cabled” network is often a useful solution to manage fixed smart objects, such as machineries and gantry cranes.\textsuperscript{15} Naturally, in port areas, when managing moving “non-static” entities (like forklifts), cables are not the right connectivity option, a wireless connection coverage is needed to achieve the Internet of Things (IoT) paradigm. LTE (4G) and 5G cellular technologies represent very useful

\textsuperscript{15}Cabled connectivity technologies need huge investments and high installation and maintenance costs.
tools, the perfect combination for dealing with the connectivity demand coming from all the numerous IoT devices in the port area.

Cellular connectivity has some peculiar and unique characteristics, such as low latency (even with a multitude of users), flexibility, high quality service, mobility capability (background roaming), which can be key aspects to achieve the goal of a smart port, which ensures a 24/7 digital and “green” services and processes optimization. Section 7.2.3 is in fact describing how Livorno has experimented a real “Port of the Future” use case in the “COREALIS”16 H2020 project and how those results can be exploited in order to enable a 5G 24/7 Port of the Future environment.

16 COREALIS project webpage is available at https://www.corealis.eu/
7.2.3 5G tests at the port of Livorno: the COREALIS H2020 project

To meet this ambitious challenge of 5G in ports, CNIT, Ericsson and the Fondazione ENI “Enrico Mattei” (FEEM) have proposed a new methodology for technology assessment. In this matter, each partner provides specific contributions and skills to reach a common vision and objective to create a comprehensive module for evaluating the impact of the new disruptive technologies and measuring their environmental impact.

Thus, thanks to the COREALIS development plan, all the port specific processes, such as warehousing, gate in/out procedures, cargo management operations, Verified Gross Mass (VGM) management, ships and goods practices and smart corridor planning are involved and analyzed in three main steps, which have been identified: (1) Sustainable Development Goals (SDGs)\textsuperscript{17} identification, (2) Port process identification and analysis, (3) Technology assessment.

\textsuperscript{17} The full UN SDGs list is available at https://sdgs.un.org/goals
The first step refers to the SDG identification, which depends on the needs and characteristics of the port. According to the “2030 Agenda for Sustainable Development”, these relevant SDGs (also shown in Figure 6) are: Quality Education (SDG 4), Decent Work and Economic Growth (SDG 8), Industry, Innovation and Infrastructure (SDG 9), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), Life Below Water (SDG 14).

Figure 6 - SDGs identified for the Port of Livorno [17].
The second step consists of port processes identification and mapping, especially considering the technology positive and revolutionising impacts. Figure 7 shows the main logistics processes taking place in the Port of Livorno.

Last step, the third one, evaluates the impact of 5G and digital technologies on the port processes with specific KPIs.

The COREALIS project trial included a 5G-based control module for general cargo management, performing real time monitoring of the loading and unloading port operations. Data collection is obtained via an ad-hoc sensor network (including LIDAR, WDR cameras) and portable devices, such as tablets.

This peculiar 5G general cargo module can identify and detect general cargo in a shorter time than the usual human-driven communication,
enabling a better management. An advanced AR/VR-based system\textsuperscript{18} provides a full terminal operation optimization [17]. Figure 8 illustrates how the 5G-driven general cargo module is structured and what are the data sources involved in the process.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{5G-driven general cargo module [17].}
\end{figure}

All the prospected direct and indirect 5G-enabled benefits on port processes has been identified and analyzed. Reports show how some port processes have been positively affected by 5G technology and

---

\textsuperscript{18} Augmented Reality (AR) adds digital elements to a live view often by using cameras, while Virtual Reality (VR) implies a complete immersion experience that shuts out the physical world.
digital solutions, such as the Internet of Things (IoT), augmented and virtual reality (AR/VR) and Artificial Intelligence-based systems.

It was found that there are sixty-five 5G-based SDG benefits, 15 direct and indirect benefits relating to automation, 32 direct and indirect benefits relating to transport and logistics, 13 direct and indirect benefits relating to environmental sustainability and personnel safety and 5 direct and indirect benefits relating to smart port for a smart city.

The transformative goals of 5G-driven technologies enable logistics projects optimization, achieving important logistics 4.0 goals, such as significant time and cost savings. Moreover, innovations improve the port logistics value chain growth and job tasks and skills, enhance port infrastructure and innovation, enable responsible production and increase the port environmental performances and carbon footprint reduction (protecting the coastal and marine ecosystems).

A peculiar public-private partnership and cooperation is therefore necessary for the aim of achieving sustainable development goals.
7.2.4 RTPORT: A real-time yard management system

A proof of concept of the RTPORT module has been implemented at the Lorenzini’s terminal at the port of Livorno. The whole general cargo\textsuperscript{19} management system has been, in this way, tested in a real operational environment, demonstrating that 5G enables functionalities that improve the operational performance of port operations.

Figure 9 shows the general cargo RTPORT use case, describing the role of each operator during goods management and handling operations.

\textsuperscript{19} General cargo refers to all those freight which is not unitized, so has no standard size and no standard weight. Storage area and handling operations are not so easy to optimize.
The general cargo logistics use case can be divided into three phases:

1. **Tracking and Storage**: this phase includes handling operations (from their arrive in the port, until they are placed in the yard);

2. **Loading Operations**: item selection (what goods have to be loaded on the ship or transferred to the crane);

3. **Yard Vehicle Call**: general cargo operations require forklift call.

The tracking and storage phase includes three operations:

1. **Collection of information** (goods acceptance procedure): the quay operator checks all the goods that are going to be unloaded
from the truck. He has to get the parcels size information from
the waybill. If size is not reported, he will use the LIDAR
measurement device for the acquisition. Then, the quay
operator writes down all data using a dedicated tablet
application and sends it to the main control system database
via the 5G mobile network;

2. **Unloading from truck**: manual unloading operation. If required,
   the forklift (or reach stacker), once the good has been picked
   out, stops and waits for the size measurement. The main control
   system searches an optimal storage location in its virtual map
   (according to a set of rules) and updates the item record in the
database;

3. **Transfer to the storage area**: the good status information is
   changed to “in transit”, the forklift driver receives driving
   information to easily reach the storage slot. When approaching,
   the driver is aided by a AR assisted position tool. Then, the
   main control system updates the object record as “placed in
 storage” and the smart cameras check the final position of the good.

The Loading Operations phase includes two operations: (1) Selection of the cargo to load, (2) Transfer to crane.

Goods must be loaded on the ship according to a precise loading plan prepared by the captain and subjected to change runtime if ship balancing operations are needed.

When items have to be transferred from the storage area to the loading area (in front of the crane), the dock operator requests to the main control system the next good to be picked. When the main control system has identified the item to be picked (and its characteristics), it choose a free forklift and sends a picking notification to the forklift driver, who uses a tablet app including driver indications and virtual GPS maps.

When approaching to the object to be picked, the driver can commute to the AR assisted positioning. If the object is located in a place which is difficult to reach (and requiring additional moving operations), the
main control system guides the operator while moving the other objects to reach the target item.

Once the target object is picked, the driver has to send a message to the main control system to state the picking operation completion. Then, the main control system updates the item record in the database, setting its status as “transferred for loading”.

The “yard vehicle call” phase is based on a 3D rendering module (MoniCA). It aims to trace and monitor the forklift resource pool and its status, in order to select and move them according to the object positioning on the yard.

Position data are the starting point for vehicle tracking and are transmitted through a 5G network to the machine-to-machine platform (OneM2M).

Data are also processed and consumed by the Port Community System (PCS) [29].
From an economical and managerial perspective, resource optimization improves the overall performance in terms of time and movement frequency, and optimizes the storage area utilization.

Stockyard areas are being controlled thanks to a very high-precision LIDAR and smart cameras\textsuperscript{20} system, which allows the "radar-laser" scanning of the items in order to identify the correct positioning and storage slot.

\textsuperscript{20} Smart cameras must take care of lighting conditions, so WDR or HRD cameras are used.
Table 12 - Environmental impact of 5G and digital technologies [17].

<table>
<thead>
<tr>
<th>Activity</th>
<th>Machines</th>
<th>Measurement in 2017 (Before 5G)</th>
<th>COREALIS project (With 5G)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hours activity/year</td>
<td>Diesel/year (m³)</td>
</tr>
<tr>
<td>Vessel loading and unloading</td>
<td>Tower crane</td>
<td>4,380</td>
<td>399</td>
</tr>
<tr>
<td>Truck yard loading and unloading</td>
<td>Forklift</td>
<td>1,575</td>
<td>43</td>
</tr>
<tr>
<td>Yard movements</td>
<td>Forklift</td>
<td>3,681</td>
<td>235</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>-</td>
<td>677</td>
</tr>
</tbody>
</table>

Table 12 reports how the reduced number of movements and the accurate forklift assignment (depending on the distance from the object to be picked up and on the availability) allows a drastic decrease of empty returns.

This has an excellent effect on the overall environmental performance of the terminal (-8.2% CO₂ emissions per year).
7.2.5 Goals and achievements

COREALIS case study has demonstrated how ports can obtain several tangible and intangible benefits by implementing 5G infrastructures. In this way, qualitative and quantitative analysis have been performed.

Qualitative analysis, results and UN-SDGs benefits, with a specific emphasis on the Port of Livorno Focus areas, are reported in Table A3, which is useful to understand what are the most important qualitative benefits of implementing and using a 5G ecosystem and what are the main goals and achievement according to the UN SDGs.

Air quality is improved due to efficiencies in terminals and port operations as 5G enables 24/7 services.

Efficiency and productivity enhance, so cost and time are reduced.

The sustainable goals taken into account consider the importance of a smart ecosystem in which working profiles can upgrade and improve, as well as the port community stakeholders. In this way, economic and
social goals are achieved. Another very important aspect is staff training, including on digital skills.

From a purely economic point of view, the innovation node competitiveness increases and this has a sensitive impact on the increased throughput of the intra-terminal logistics operations.

Table 13 collects and lists ad-hoc Key Performance Indicators (KPIs), and then provides a detailed overview of the advantages that a port terminal may have when adopting 5G technology.
Table 13 - Quantitative benefit, enabled by 5G, in container intra-terminal operations [17].

<table>
<thead>
<tr>
<th>Operation</th>
<th>KPI (average value)</th>
<th>KPI baseline</th>
<th>KPI COREALIS target</th>
<th>What improved</th>
<th>Benefited stakeholder</th>
<th>Environmental analysis</th>
<th>What improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessels berthing time</td>
<td>Vessel operation completing time</td>
<td>18 h</td>
<td>16 h</td>
<td></td>
<td>Shipping company</td>
<td>CO₂ saving per container operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vessel idle time at berth</td>
<td>36 h</td>
<td>34 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cargo release</td>
<td>Loading (on ship) / unloading (from a single truck) operations completion time</td>
<td>18 h / 40 min</td>
<td>16 h / 30 min</td>
<td>Increased operational speed</td>
<td>Hauliers</td>
<td>8.2% CO₂ saving</td>
<td>Fuel reduction</td>
</tr>
<tr>
<td></td>
<td>Time to find a pallet on the yard</td>
<td>8 min</td>
<td>7 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cargo registration completion time</td>
<td>3 min</td>
<td>2 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage of cargo physical characteristics information registered electronically</td>
<td>0.9</td>
<td>0.95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quays and yards operations</td>
<td>Forklift operation execution time</td>
<td>8 min</td>
<td>7 min</td>
<td>Reduced operational cost</td>
<td>Terminal operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Occupied space during the storage phase</td>
<td>5,000 m²</td>
<td>4,500 m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage time of activity / inactivity of the forklift</td>
<td>60% / 40%</td>
<td>65% / 35%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total number of movements per cargo unit</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8 Livorno “Smart Landscape”

8.1 Smart city and smart ecosystem

In this Chapter the concept of “Smart Landscape” encompassing that of “Smart Cities” and connected “Smart Environments” will be introduced. As the Italian territory is characterized by the presence of several logistics and maritime hubs, close (or even fully integrated) with urban settlements, it is essential to meet a "smart" integration between cities and their ports. Port and municipality authorities are indeed expected to jointly address the sustainable development of maritime businesses.

Ports and cities are historically connected and the growth of the former is not fully achievable without biasing the daily life in the urban settlement. New technologies and the rise of digital hubs in ports and smart cities permit to co-design the “Smart Landscape” letting wealth, businesses and employment grow without disrupting the quality of life of citizens and workers.
The Case Study of the Port of Livorno where the technological push offered by 5G technology is offering a motivation for adopting a “Smart Landscape” approach as promoted by government agencies for the public and private sectors.

The smart city model is more and more adopted at European and national scales. It proposes solutions and use cases which are all characterized by limited validity, because it is related to the urban context and to the “Citizen”, without considering the opportunities deriving from the integration with other constituents of our societies (e.g., Industrial Communities, manufacture plants, logistics, etc.). Thus, from an economic, environmental and social perspective, attention must be paid to a wider and more complex system, often referenced as “Smart Landscape”, ready for a synergic, coordinated and integrated approach, optimizing investments in efficiency while guaranteeing a decent quality of life to citizens and workers.

Along this line, logistics represents an industrial policy strategic instrument, as it enhances the excellence of the production system
while promoting the development of eco-sustainable transport solutions.

Worldwide technology investments on smart city initiatives is forecast to more than double between 2018 and 2023 (from 81 billion U.S. dollars in 2018 to 189.5 billion in 2023) [30]. The national programs on the subject of Smart Landscape (“AgID Three-Year Plan 2019-2021”) [31], should therefore be synergically framed into a broader perspective, to make the vertical solutions interoperable, in order to achieve an intelligent and safer passenger and goods transportation management and by promoting the development of services designed and implemented on the basis of citizens and business needs.

In this regard, new ICT technologies (such as 5G, Artificial Intelligence, Internet of Things and Blockchain) are needed for a sound and effective realization of the “Smart Landscape”. Urban areas, as well as the logistic nodes, represent complex dynamic (non-linear) systems, since an action on any of the subsystems has effects and impacts also on other subsystems. The propagation of an action could therefore determine final results that are not directly quantifiable in
terms of overall benefits. Thus, port and urban areas can be studied with the same tools and technical solutions are worth to be provided to their composite system avoiding discontinuities and maximizing the effects [32].

The Livorno port, favourably situated in western Tuscany, plays a major role in the European internal trade, ensuring frequent and fast maritime connections to southern European countries, as well as in the EU external trade, thanks to its well-established linkages to northern African countries and the Americas. Livorno is also considered a pivotal node in the logistic chains linking the Mediterranean to central-east Europe. The Port Authority in collaboration with CNIT designs and supervises the implementation of the digital agenda tailored to the Port Communities and the neighbour City [21]. Both public organizations are asked to comply with AgID roadmap for digitalization of the public sector.

Among the lines of action of the AgID “Three-Year Plan for Information Technology in Public Administration 2019-2021”, a “Smart Landscape Platform (SLaP) for Administrations” is proposed as a managerial tool to
turn smarter the whole Public Administration sector [32]. More specifically each administration willing to be "smarter" is expected to provide its own services and its related APIs (or use those already available in the SLaP platform) avoiding duplications (or overlaps) and favoring the re-use and integration of innovative solutions that are already being operationally tested.

The digitization process includes process re-engineering, risk analysis, integrated control and, lastly, a "full-digital" business approach. The digitalization level of Public Administration is then measured by specific KPIs linked to specific rankings, such as those established by the World Bank and the World Economic Forum. Among others, KPIs assess the level of digitalization, openness, the number of available "full-digital" services, the level of data security and privacy protection.

Everything related to the digitization process is based on a paradigm where Public Administrations are active drivers of growth. The paradigm is based on stakeholders’ engagement (throughout all the process phases, from “vision” to “execution”), on culture building, on implementation rules definition.
Network planning (notably that of 5G) is definitely a matter of port-
city co-design configuring the city as the host and the port
communities as the beneficiaries of this new technology.

In our case of port-city development towards the “Smart Landscape”
the following targets must be accomplished:

- to integrate existing services in a newly fully interoperable
  service oriented architecture;
- to strengthen the interaction between citizens, businesses and
  PAs through an environment where Digital Communities,
  Living Labs and user clusters can cross-fertilize;
- to create a virtuous interaction with citizens and industries
  through "gamification" techniques applying the principles of
  behavioural economics in order to induce subjects to virtuous
  conducts;
- to define and disseminate guidelines, directives, and best
  (standard) practices.
8.2 Future prospects and targets

Cities, as well as industries and economic districts are incubators of innovation and smartness, so they are turning into smart environments.

City and port, moving from two standalone realms, are requested to interconnect into a digitalized smart environment, a Smart Landscape where people and industries co-work for sustainable growth and well-being. The new communication standards will give a boost to the technological innovations, offering a real revolution in relationships, working, education and mobility.

By combining 5G networks, IoT and Artificial Intelligence, all considered in a common pool, on one hand cities will become smart, efficient and sustainable, on the other hand ports will reduce energy consumption and pollution.

Port of Livorno is becoming a data hub, enabling the monitoring of people, processes, and assets throughout the logistics and maritime processes. 5G networks is permitting a higher degree in data collection
and sharing. This will offer Port of Livorno visibility and predictability as already decided in the approved digital agenda [24].

The Port of Livorno represents a perfect environment for testing prototypes and applications on the field. It hosted the 2016 edition of ETSI Plugtests on Cooperative ITS and the AUTOPILOT autonomous driving tests in 2018.

During the 2019 “Digital Transport Days”, the laboratory has also been invited by the European Commission DG CNECT with the purpose of illustrating the 5G and IoT experimentations outcomes at the Port of Livorno acknowledging its role at the European level in the logistics sector.

In 2019, Port of Livorno trials and results have been presented at the Columbia University of New York during the “Climate Week”, in order to demonstrate the positive impact of 5G on the sustainable growth, while in 2020 it obtained the prestigious “Industrial Energy Efficiency Award” at Hannover Messe Digital Days.
City of Livorno is also innovating on data management and innovation processes. Therefore Livorno is a potential Smart Landscape, with the two smart environments (the port and the city) more and more integrated in the same digital network.

Design and deployment of the new 5G network is offering a benchmark for such an integration.
9 Conclusion

Technology challenges and disrupting innovation, as well as the research and development activities in the digitalization and communication sector are revolutionizing the way supply chain actors are used to interact.

Ports are involved in the “Industry 4.0” revolution, becoming smart innovation hubs and innovation incubators. In this sense, standard C-Port services are needed, in order to create a smart environment, with the goal of improving operational efficiency and sustainable growth. A smart port vector is calculated in order to assess the port willingness to invest in digitalization, according to specific innovation bundles, in relation to their actual and evolutionary "smartness".

Thanks to digitalization and 5G revolution, 24/7 Livorno is considered a reference, as smart port and smart cities will cooperate together to create a smart landscape, with a strong inclination to a sustainable growth.
Appendix

*Table A1 - C-Ports service characteristics and benefits according to the port community (personas, stakeholders) [21].*

<table>
<thead>
<tr>
<th>Shareholder</th>
<th>Service</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping company</td>
<td>Day 1</td>
<td>• Real time tracking and monitoring, both at sea and at berth can be useful to calculate an accurate ETA/ETD and to prevent time losses and unpleasant situations;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• In-port smart navigation helps haulers to optimize their trips and to coordinate their activities according to terminal and ship availability, avoiding dead times, according to safety and security requirements;</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>A system for accidents at sea prevention is strictly recommended to prevent monetary losses due to damages and delays.</td>
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<tr>
<td></td>
<td>Day 2</td>
<td>Vessel maneuvering in port data is based on several aggregated and integrated data (such as meteomarine, bathymetric, satellite and HD video sources.</td>
</tr>
<tr>
<td>Terminals</td>
<td>Day 1</td>
<td>Real time vessel positioning and cargo details are useful to define an accurate terminal operations.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>Accident prevention and optimized forklift allocation, avoiding empty trips, and cargo pervasive monitoring in port areas, including the stocked cargo full monitoring.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>Terminal operators can benefit of a dynamic service pricing and tariffs.</td>
</tr>
<tr>
<td>Citizens</td>
<td>Day 1</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>• Pollution level and noise reduction contribute to increase the citizen well-being;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduced road traffic (due to a heavy vehicles traffic reduction).</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>According to special tariffs based on the green impact of the logistics chain operators, citizens can have indirect benefits in terms of air and water pollution reduction.</td>
</tr>
<tr>
<td>Local SMEs</td>
<td>Day 1</td>
<td>Real time cargo monitoring is important for the post-sales customer service: producers can easily track their products both at sea and on the other steps of their specific supply chains.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>According to the cargo transportation and handling operations, real time cargo monitoring is a critical aspect, especially for all those goods which require a special treatment such as:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• reefer cargo: perishable goods, food and beverage, pharmaceutical products;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• dangerous goods: gas, explosive goods, flammable liquids etc.;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• high value cargo: cars and products characterized by modest dimensions and weight and high value.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
<tr>
<td>Shareholder</td>
<td>Service</td>
<td>Benefits</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Freight forwarders</strong></td>
<td>Day 1</td>
<td>Real time full information about cargo, both at sea and in the port (e.g. full information about terminal operations and handling) is important for the logistics flow management. It is known that delays demurrage and demarage cause huge extra-costs, thus, deadlocks prevention is severely recommended;</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>Cargo perishment prevention, using sensorized containers and other IoT technologies, allow an immediate repairing action in order to prevent cargo irreversible damage. According with this, a reefer cargo monitoring platform will be supplied;</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
<tr>
<td><strong>Haulers</strong></td>
<td>Day 1</td>
<td>Real time information is useful to optimize the port area access time slots.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>• Accident prevention and optimized vehicle routing; • Gate automation based on an authorization system.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>Hauliers can benefit of a dynamic pricing system and obtain an ad-hoc service tariff based on the environmental impact.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
<tr>
<td><strong>Tourism operators</strong></td>
<td>Day 1</td>
<td>Info-mobility real-time information, journey planning and trip management are value-added service which can be offered to a tourist.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>/</td>
</tr>
<tr>
<td><strong>Tourists</strong></td>
<td>Day 1</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>• MaaS and info-mobility travel planner; • “In-port” autonomous driving is extremely important for the pedestrian safety and for the accident prevention; • Integrated tourism platform, including both transport information, tourism points of interest and accommodations; • The integration with TCC is useful to provide real time information.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
<tr>
<td><strong>Commuters</strong></td>
<td>Day 1</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>• MaaS and info-mobility travel planner, with a full network information (traffic jams, line interruption and maintenance etc.) is a valid ICT tool for all the people who need to reach the workplace every day, using both private and public transport; • Autonomous driving, which is an important safety and security aspect in port areas, helps to prevent accidents and traffic jams.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
<tr>
<td>Shareholder</td>
<td>Service</td>
<td>Benefits</td>
</tr>
<tr>
<td>-------------</td>
<td>---------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| Insurance companies | Day 1 | ▪ Information coming from the c-port IT infrastructure can be a valid instrument to calculate the riskiness of a certain operation. In this sense, data can be combined and integrated in order to obtain specific risk measurement parameters;  
▪ In case of cargo damage, fires or accidents at sea, accurate vessel positioning, full information about cargo and Vessel-Port bi-directional communication (share of digital resources) is important to reconstruct what happened. Then, the insurance company will compute the right insurance claims;  
▪ In case of accidents and damages happened during the berthing and docking operations, we can state the same consideration as in the previous point: a full tracked berthing operation is very important to establish contractual responsibilities in the event of a claim, such as ship hull damages or groundings;  
▪ Freight management and control operations are useful to understand, in case of fire, damage or cargo perishment, the amount of the insurance compensation and who are the responsible actors according to the real causes and the real accident dynamics;  
▪ In-port smart navigation systems avoid accidents mitigating the risk of safety and security claims, defining a safe and secure path. |
| | Day 1.5 | ▪ Adopting smart systems to prevent vessels and/or cargo accidents at sea and suspicious vessel maneuvers, in order to calculate an adequate insurance premium and to prevent extra-costs deriving from insurance indemnities;  
▪ Port-to-port, port-to-road and port-to-railways communications can prevent insurance claims connected to a wrong freight routing plan;  
▪ A distributed monitoring network, connecting the ocean domain to the landside by the IoT paradigm is used to mitigate several logistics insurance risks (B.5). In this sense, an integration with the Traffic Control Centre is required;  
▪ Crew personnel, port personnel and port maneuvering crew can incur in several accidents or fatalities due to the riskiness of their job. A fully sensorized port can be a safer workplace for all these categories of workers;  
▪ Seaport areas represent dangerous places for pedestrians and drivers. In this sense, autonomous driving and in-port smart mobility can be a valid instrument for mitigating several risk factors linked to safety and security in port areas. |
| | Day 2 | A smart ship (real-time) control platform will mitigate the risk of failures on the ship and caused by the ship. |
### Table A 2 - C-Ports service characteristics and benefits according to the Public Authority partners [21].

<table>
<thead>
<tr>
<th>Partners</th>
<th>Service</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Authority</td>
<td>Day 1</td>
<td>Real time and reliable cargo ship information and accurate vessel positioning is full available.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>- Real time information and statistics about the transport network status are important for the port activities planning operations;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Using pollution control systems and dynamic service pricing based on how green the processes are, environmental goals are easier to achieve.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>Dynamic “ecological tariffs” are fundamental factors to improve the port green impact.</td>
</tr>
<tr>
<td>Coast Guard</td>
<td>Day 1</td>
<td>Vessel traffic management and berth allocation and docking control are important aspects for the Coast Guard surveillance activities.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>Satellite information can help preventing suspicious maneuvering and route changes.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>Autonomous ships and autonomous maneuverings in port water are important aspects according to the coast monitoring and control activities. This kind of “smart-navigation” better meets safety and security navigation requirements.</td>
</tr>
<tr>
<td>Customs Office</td>
<td>Day 1</td>
<td>Thanks to blockchain technologies, reliable and trusted information about cargo is available and helps the Custom Office operations organize freight border control, avoiding time wasting due to document checking.</td>
</tr>
<tr>
<td></td>
<td>Day 1.5</td>
<td>An accurate freight routing is useful to reconstruct the path followed by all the specific cargo shipping lots along the supply chain.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>Day 1</td>
<td>/</td>
</tr>
<tr>
<td>Public transport</td>
<td>Day 1.5</td>
<td>Info-mobility platforms and MaaS apps allow data aggregation and offer tailor-made services to all the passengers (both commuters and tourists). A full integration with TCC is strongly recommended.</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
<td>/</td>
</tr>
</tbody>
</table>
Table A3 - Results from the overall qualitative analysis [17].

<table>
<thead>
<tr>
<th>Port process</th>
<th>Focus Area</th>
<th>Benefits enabled by 5G</th>
<th>Contributions to UN SDGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container terminal operations</td>
<td>Automation</td>
<td>Lower vessel completion time, improved personnel safety, fewer human mistakes and operational inefficiencies, and working profile upgrade.</td>
<td>4, 8, 9, 11, 12, 13, 17</td>
</tr>
<tr>
<td></td>
<td>Transport and logistics</td>
<td>Improved security/safety during navigation, new business models, increased number of stakeholders involved in data exchange, and reduced maintenance costs, CO2 and power consumption.</td>
<td>4, 8, 9, 11, 12, 13, 17</td>
</tr>
<tr>
<td></td>
<td>Environmental sustainability and personnel safety</td>
<td>Less exposure to polluting agents for on-field personnel, CO2 and environmental impact reduction, new job opportunities and shorter intervention time for specialized personnel.</td>
<td>4, 8, 9, 11, 12, 13, 14, 17</td>
</tr>
<tr>
<td></td>
<td>Cybersecurity</td>
<td>Improved security for sensible data transmission, better capacity to identify potential threats, greater data reliability and new professional figures.</td>
<td>4, 8, 9, 11, 12, 17</td>
</tr>
<tr>
<td>VGM</td>
<td>Automation</td>
<td>Reduced weighing times, lower environmental impact and a higher number of weighing per time units</td>
<td>9, 11, 13, 17</td>
</tr>
<tr>
<td></td>
<td>Transport and logistics</td>
<td>Improved data integrity, faster data elaboration, better stowage planning and reduced truck waiting times</td>
<td>8, 9, 11, 12, 13, 17</td>
</tr>
<tr>
<td>Warehouse management</td>
<td>Automation</td>
<td>Lower time to find cargo, reduced accidents, less operational inefficiencies, fewer human mistakes, lower handling time per cargo unit, reduced economic costs and improved competitiveness</td>
<td>4, 8, 9, 11, 12, 13, 17</td>
</tr>
<tr>
<td>Ship practices (loading, unloading, trailer, piloting)</td>
<td>Transport and logistics</td>
<td>Smart and autonomous vehicles for cargo handling and monitoring</td>
<td>Lower time to find cargo, reduced accidents, less operational inefficiencies, fewer human mistakes, lower handling time per cargo unit, reduced economic costs and improved competitiveness</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Transport and logistics</td>
<td>Remote assistance and monitoring of ship practices through distributed sensors and cameras communicating in real-time to the MIoT system and with AR/VR assistance for drivers</td>
<td>Reduced risk of accidents and economic losses, lower time for maneuvers, operation optimization, greater safety, positive outcomes for updating education programs, and on-the-job and continuous training</td>
<td>4, 8, 9, 11, 12, 14, 17</td>
</tr>
<tr>
<td>Environmental Sustainability and personnel safety</td>
<td>Monitoring the seabed, terminals and other port infrastructures with a distributed sensor system and MIoT cameras</td>
<td>Major safety through 5G-enabled MIoT sensors and the reduction of accidents</td>
<td>4, 8, 9, 11, 12, 13, 14, 17</td>
</tr>
<tr>
<td>Controlled corridors</td>
<td>Cargo tracking truck appointment system with an MIoT network distributed over the entire area, connected with RSU, AR, control centers and other trucks</td>
<td>Reduced traffic congestion, a decrease in pollution, increased visibility of load and road safety, positive consequences for updating education programs, and on-the-job and continuous training</td>
<td>4, 8, 9, 11, 12, 13, 17</td>
</tr>
<tr>
<td>City/port relations</td>
<td>Smart corridors for real-time monitoring/control and infomobility services for passengers in the concept of Smart City</td>
<td>Improved mobility, reduction of environmental impact, greater control over processes, positive consequences for updating education programs, and on-the-job and continuous training</td>
<td>4, 8, 9, 11, 12, 13, 17</td>
</tr>
</tbody>
</table>
References


[19] Ericsson, "Digital Ports".


[30] Statista, "Technology spending on smart city initiatives worldwide from 2018 to 2023".
